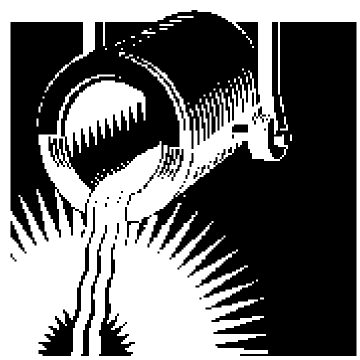
Metal Casting

Annual Report 1999



May 2000

Metal Casting Industry of the Future
Office of Industrial Technologies
Energy Efficiency and Renewable Energy
U.S. Department of Energy

Metal Casting Annual Report
1999

CONTENTS

EXHIBITS

The Metal Casting Annual Report, 1999 summarizes the activities and accomplishments of the Metal Casting Industry of the Future Program during 1999.

For additional copies or to obtain OIT publications, contact the OIT Clearinghouse at: (800) 862-2086 or visit our website at: <www.oit.doe.gov>.

For additional information contact:
Harvey Wong
Metal Casting Program Manager
U.S. Department of Energy
Office of Industrial Technologies
1000 Independence Ave., SW

Prepared by:
BCS, Incorporated

INTRODUCTION

The Department of Energy's (DOE) Office of Industrial Technologies (OIT) has established a highly successful partnership with the metal casting industry. This industry-government partnership, the Metal Casting Industry of the Future (IOF), is coordinated through the Cast Metals Coalition (CMC). The CMC is composed of the American Foundrymen's Society (AFS), North American Diecasting Association (NADCA), the Steel Founders' Society of America (SFSA) and the Advanced Technology Institute (ATI). Collectively, this coalition represents the majority of the U.S. metal casting industry.

Each year, the Metal Casting Industry of the Future publishes an Annual Report to review its research portfolio and accomplishments for the year and to provide background information on the program. The contents of this report include:

- Background information on the Metal Casting Industry of the Future research partnership and OIT's energy efficiency goals for that partnership
- A brief review of metal casting market data
- Significant accomplishments and research developments for 1999 and examples of progress in reaching energy goals
- A review of the Program's research portfolio.

Metal Casting Research Partnership

The IOF strategy fosters government-industry partnerships in economically vital, energy intensive U.S. industries, including metal casting. Through IOF, OIT encourages each of the most energy-intensive industries to develop a vision of their future, next these government/industry partnerships cost-share pre-competitive R&D. This research is advancing energy efficiency, promoting environmentally sound manufacturing processes, and increasing industry competitiveness.

Background

The Department of Energy Metal Casting Competitiveness Research Act of 1990 (P.L. 101-425) was designed to improve competitiveness and energy efficiency in the metal casting industry. The Metal Casting Industry of the Future builds upon the foundation put in place by the Act. It fosters collaborations between universities, national laboratories, and industry.

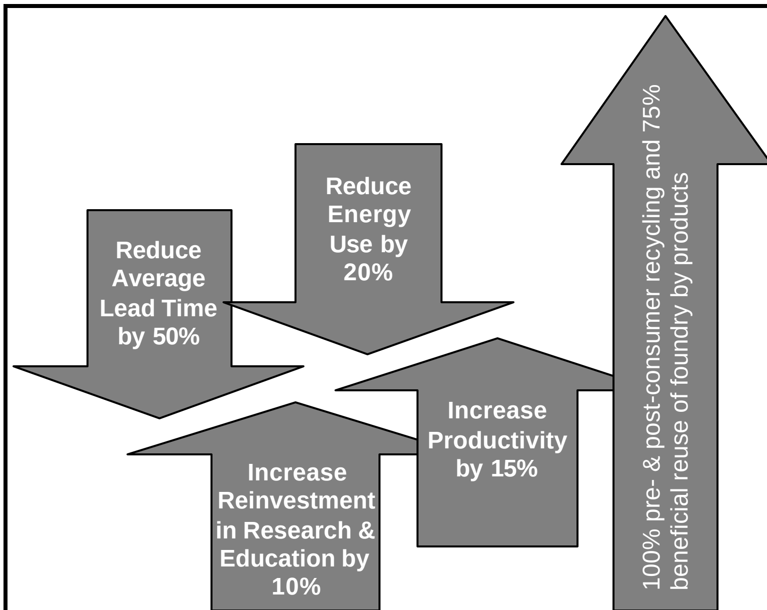
Through industry visions and technology roadmaps, metal casting industry participants set technology priorities, assess the progress of R&D, and lead the way in applying research results. See Exhibit 1 for industry goals outlined in *Beyond 2000: A Vision for the American Metal Casting Industry*. Additional information on the Vision, Roadmap and solicitation process is provided in Appendix A. This approach to private-public partnerships ensures strategic allocation of limited resources for the development of new technologies and the enhancement of metal casting processes. It is through this partnership that results are tested, disseminated and applied throughout the industry.

A Successful Approach R&D Partnerships

The involvement of industry on the ground floor helps to speed the pace of technology transfer and the dissemination of research results. The Metal Casting Industry of the Future cost shares research projects that have broad application across industry. The current participation of nearly 250 companies from 32 states is evidence of the industry-wide importance of program-funded research. These industry partners represent the diversity of metal casting – utilizing a range of casting processes and supplying cast products to an array of casting markets.

Exhibit 2 shows locations of research performers and industry partners across the U.S. It illustrates the broad reach of the metal casting research partnership. Industry and university partners and their locations are listed by state in Appendix B.

Exhibit 1
Metal Casting Vision Goals

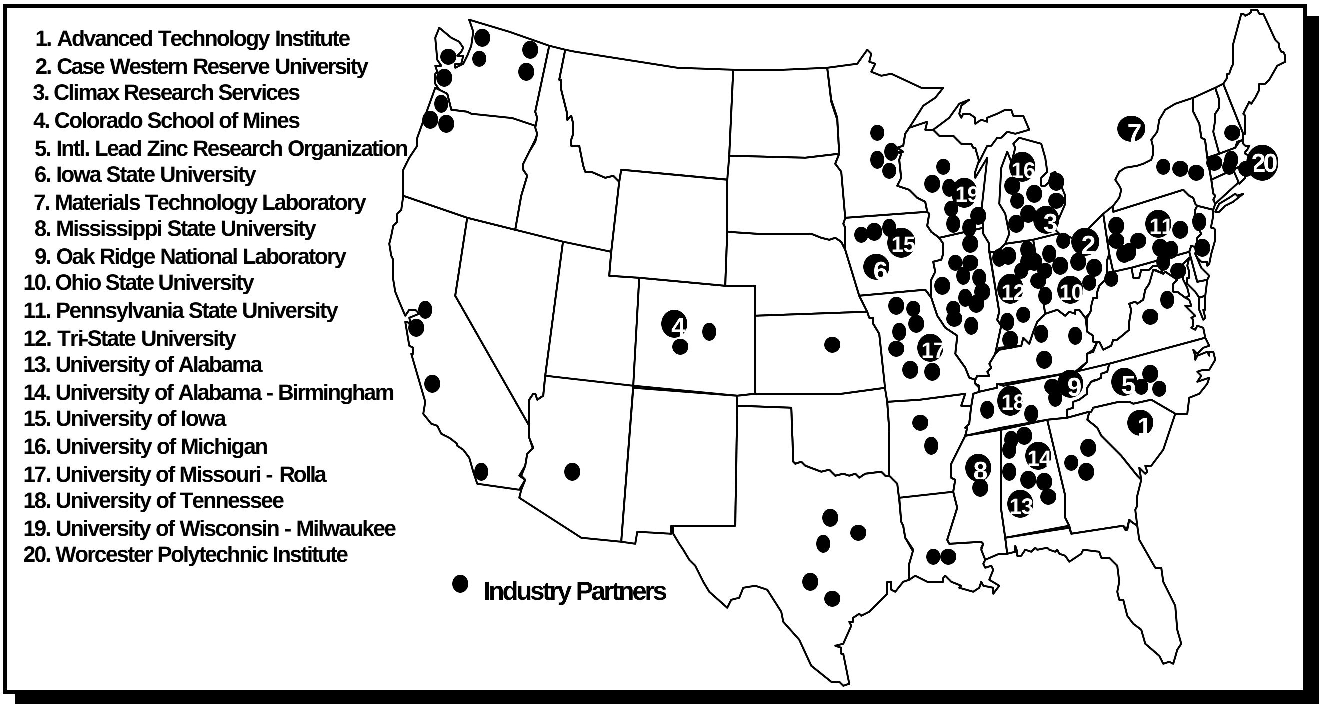


In 1995, the metal casting industry published *Beyond 2000: A Vision for the American Metalcasting Industry*. It outlines specific goals for the industry over the next 20 years. In 1998, the Metal Casting Industry Technology Roadmap was published. The Roadmap outlines research pathways needed to achieve Vision goals. It forms the basis for cost-shared research performed through the Metal Casting Industry of the Future.

The Industries of the Future approach is becoming a model internationally. For example, at the International Casting Conference held in September 1999, industry representatives from other countries were seeking to identify how successful government-industry research partnerships can be formed. The relationship created through the Metal Casting Industry of the Future partnership was characterized as "the right way to carry out baseline research to assist whole industries."[1] Industries in other countries are looking to the IOF approach as an example to follow.

[1] "NADCA Participates in International Casting Conference in England", William A. Butler, *Die Casting Engineer*, January/February 2000.

Exhibit 2
Research Performers and Project Partners



Energy Benefits and Performance Measures

Metal casting was selected as an Industry of the Future because it is one of the most energy-intensive U.S. industries. The U.S. metal casting industry consumes an estimated 200 trillion Btu per year.[2] The major energy consuming processes in metal casting include: coremaking, moldmaking, melting, heat treatment and post-cast activities. The most energy intensive of these processes is melting. Melting accounts for an estimated 55% of process energy costs.[3]

Gray and ductile iron castings account for about 70% of casting production. As illustrated in Exhibit 3, the primary sources of energy in gray and ductile iron casting are electricity, coal/coke, and natural gas. Within iron production foundries, an estimated 51% of cast iron production is made via cupola melting. Cupola furnaces rely heavily on coke as an energy source. Nearly half of merchant coke production capacity is for foundry coke (1.4 million tons).[4]

---

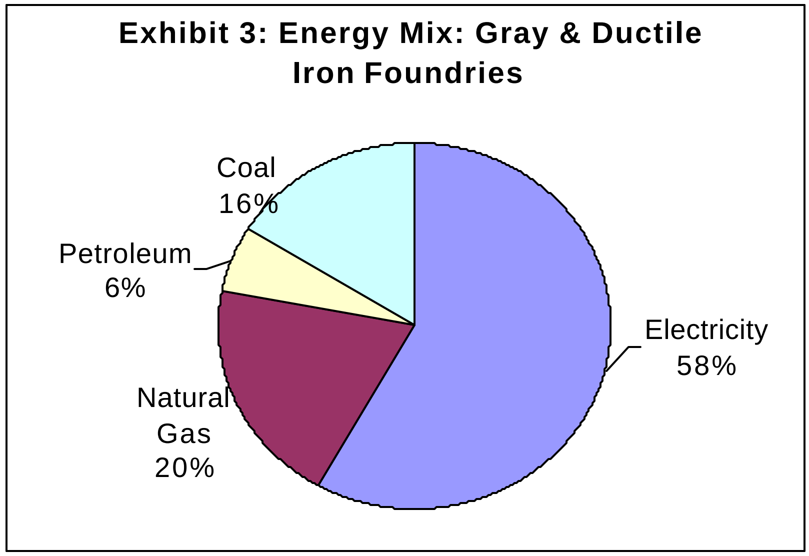
[2] *Energy and Environmental Profile of the U.S. Metalcasting Industry*, U.S. Department of Energy, Office of Industrial Technologies, p. 10.

[3] ibid.

[4] Source: *Modern Casting*, “Charge Material Issues Examined by Ferrous Foundrymen”, January, 1998, p 50.

Addressing Energy Efficiency Goals

Research funded through the Metal Casting Industry of the Future is helping to improve energy efficiency in the industry. In so doing, it is striving to achieve both industry and national goals. As stated in the Office of Industrial Technologies Strategic Plan, major goals of the U.S. Department of Energy and the Office of Industrial Technologies are: *"a 25 percent improvement in energy efficiency and 30 percent reduction in emissions for the vision industries by 2010"* and *"a 35 percent improvement in energy efficiency and 50 percent reduction in emissions for the vision industries by 2020."* The Strategic Plan states that "OIT will motivate and will assist industry to develop technology solutions to critical energy and environmental challenges... ."



Source: Energy and Environmental Profile of the U.S. Metal Casting Industry, U.S. Department of Energy, Office of Industrial Technologies

Measuring Progress

Each year, the Program reports to Congress its progress in achieving energy goals in response to the Government Performance and Results Act (GPRA). To better assess this progress, the Program has identified specific performance measures. The Program is tracking progress in each of these performance measures to evaluate the impact of its metal casting research portfolio. These performance measures are:

- **Yield Improvement / Scrap Reduction** - Program-supported research will assist the industry to achieve 10% combined yield increases and scrap reduction by 2020.

- **Melting Efficiency** - Program-supported research will assist the industry to improve melting efficiency to achieve a 2% energy savings industry wide by 2020.

- **Environmental Benefits** - Virtually all of the research supported by the Metal Casting Program generates direct and indirect environmental benefits for the foundry industry. These are accomplished through energy savings and associated emissions reductions, scrap reduction, reductions in disposal requirements and other measures.

IOF research is resulting in advances in cutting edge design, materials and processing, and manufacturing technologies. This is allowing the metal casting industry to achieve measurable improvements in each of the performance measure areas and is helping to improve energy efficiency.

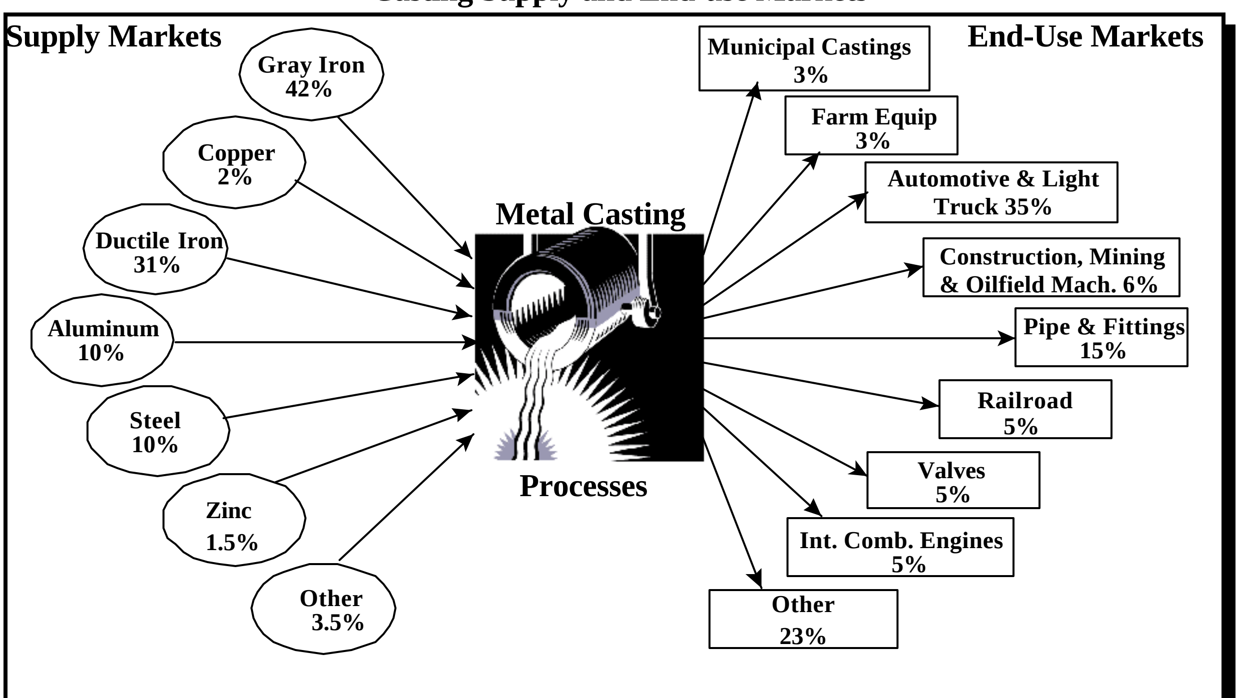
MARKETS IN BRIEF

A vibrant, competitive and energy-efficient metal casting industry is vital to the U.S. economy. Cast products can be found in virtually every sector of the economy. Metal casting is the chosen metal forming technique for 90 percent of all manufactured goods and nearly all manufacturing and machinery. Cast manufactured components include automotive parts such as engine blocks, transmission housings and suspension parts. Castings are used in parts for pumps and compressors, pipes and fittings, mining and oil field equipment, recreational equipment, and surgical equipment. Exhibit 4 illustrates supply and end-use markets for castings.

Markets for castings are increasingly competitive and customers for cast metal products are placing greater demands on the industry for high quality, competitively priced castings. As Exhibit 4 illustrates, the largest market for metal castings is the automotive sector. Increasingly, automotive markets are exhibiting increasing demand for light-weight, high strength cast metal components to respond to fuel economy requirements.

The Metal Casting Industry of the Future is co-funding research to address these and other needs while simultaneously responding to the Metal Casting Program energy performance measures of: *yield improvement/scrap reduction, melting efficiency, and environmental benefits*. For example, the lost foam process holds promise in that it can be used to produce complex, dimensionally

Exhibit 4
Casting Supply and End-use Markets



Source: U.S. Department of Commerce, Bureau of Census, *Current Industrial Reports* , and American Foundrymen's Society, *Facts & Figures about the U.S. Casting Industry* accurate castings. Program-funded research has helped to significantly reduce scrap in lost foam foundries and therefore pave the way for increased use of the lost foam process. Similarly, research on late stream inoculation for ductile iron is identifying measures to improve microstructures and to produce consistently high properties. Consequently, design strengths used for ductile iron castings can be raised, leading to lighter weight iron castings. This research will enable greater application of ductile iron casting for components in automobiles and other transportation applications.

There are 2,950 foundries located throughout the U.S. The industry has a capacity to ship 17.7 million tons of castings annually. Seven states accounted for 74% of all casting shipments in 1997: Ohio (16%), Indiana (12%), Wisconsin (12%), Alabama (11%), Michigan (10%), Pennsylvania (7%), and Illinois (6%).[5] Metal casting is a small business industry. The industry employs 225,000 people. Eighty percent of foundries employ less than 100 people. Fourteen percent employ 100 to 250 people and six percent employ more than 250 people.

Exhibits 5 shows U.S. producer shipments of castings for 1997 and 1998. The U.S. metal casting industry saw healthy growth in 1998. Shipments grew over three percent in 1998 to 14 million short tons. This is the second straight year of growth in casting shipments. Gray and ductile iron continue to represent nearly 75% of U.S. casting shipments. The rate of growth in shipment was most significant, however, for aluminum and steel castings where shipments increased 5.1% and 8.7% respectively. Exhibit 6 shows the value of casting shipments for 1997 and 1998.

Exhibit 5
U.S. Producers' Shipments of Nonferrous and Ferrous Castings (short tons)

Nonferrous Castings	1997	1998	% change
Aluminum and aluminum-based alloy	1,413,234	1,485,957	5.1
Copper and copper-base alloy	260,188	273,324	5.0
Magnesium and magnesium-base alloy	18,903	19,940	0.3
Zinc and zinc-base alloy	209,248	209,864	0.2
Total Non-ferrous	1,901,573	1,989,085	4.6
Ferrous Castings	**1997**	**1998**	**% change**
Ductile Iron	4,324,723	4,484,296	3.7
Gray Iron	5,937,606	6,021,497	1.4
Malleable Iron	271,763	271,071	-0.3
Steel	1,218,452	1,323,872	8.7
Total Iron and Steel	11,752,544	12,100,736	2.9

Note: does not include lead castings; does not include non-ferrous investment castings and steel investment castings.
Source: U.S. Department of Commerce, U.S. Census Bureau, *Current Industrial Reports*, Iron and Steel Castings 1998, MA331A(98)-1, Table 3; Non-Ferrous Castings 1998, MA331E(98)-1, Table 1.

[5]American Foundrymen's Society, *Facts & Figures about the U.S. Foundry Industry.*

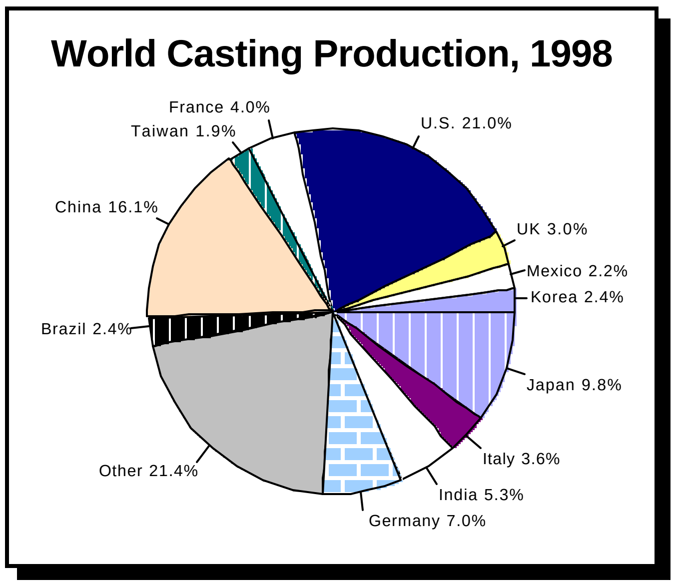
Exhibit 6
Value of Shipments of Nonferrous and Ferrous Castings ('000 dollars)

Nonferrous Castings	1997	1998	% change
Aluminum and aluminum-based alloy	$4,295,219	$4,313,880	0.4
Copper and copper-base alloy	898,722	950,026	5.7
Magnesium and magnesium-base alloy	224,426	228,174	1.7
Zinc and zinc-base alloy	769,523	850,202	10.5
Total Non-ferrous	6,187,890	6,342,282	2.5
Ferrous Castings	**1997**	**1998**	**% change**
Ductile Iron	$4,148,900	$4,326,400	4.3
Gray Iron	4,719,500	4,639,200	-1.7
Malleable Iron	272,400	258,300	-5.2
Steel	2,343,500	2,488,300	0.6
Total Iron and Steel	11,484,300	11,712,200	1.9

Note: does not include non-ferrous investment castings.
Source: U.S. Department of Commerce, U.S. Census Bureau, *Current Industrial Reports*, Iron and Steel Castings 1998, MA331A(98)-1, Table 2; and *Current Industrial Reports*, Non-Ferrous Castings 1998, MA331E, Table 2.

Exhibit 7 illustrates world casting production for 1998.[6] In Mexico, shipments grew 17.4 percent to 1.44 million metric tons. This is a 111 percent increase over the past five years. In Canada, shipments increased nearly 7 percent to 0.943 million metric tons. In Europe, Germany shipped 4.44 million metric tons, an 8 percent increase from last year. According to the 33rd Census of World Casting Production – 1998, published by the American Foundrymen's Society, other European producers also saw increases including Italy, the United Kingdom and France.

Exhibit 7



[6]Source: "33rd Census of World Casting Production – 1998", *Modern Casting*, December 1999, p. 41. Note: data for India are 1997 data.

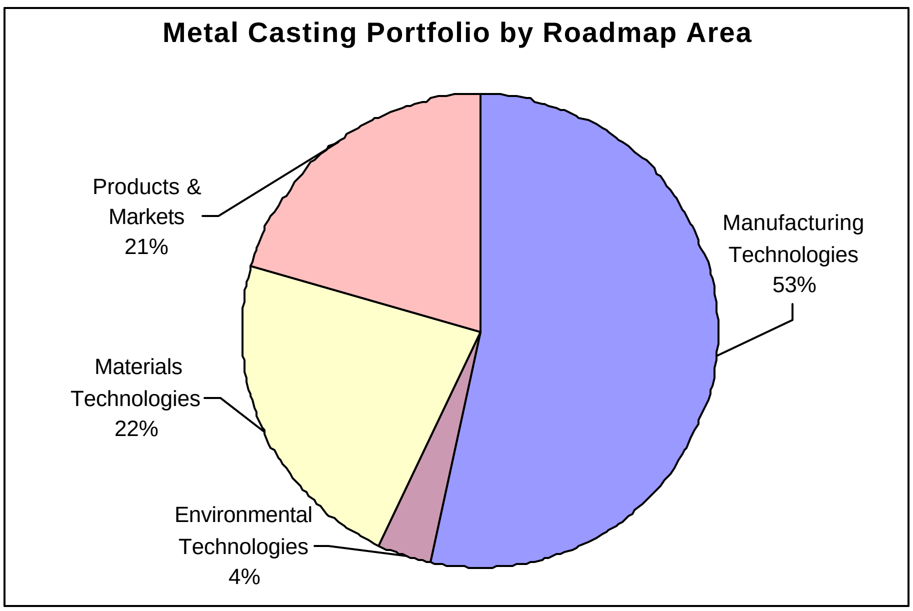
METAL CASTING RESEARCH PORTFOLIO

The Metal Casting Industry of the Future Program is currently supporting cost-shared research on forty research projects around the U.S. Research projects selected by OIT strive to improve energy efficiency in the U.S. metal casting industry. These projects address pre-competitive research needs, including high risk/high impact research, applicable throughout the U.S. metal casting industry. By emphasizing both energy efficiency and competitiveness, this government-industry partnership aspires to enable the U.S. metal casting industry to become the preferred supplier of net- or near-net-shape metal components while continuing to be globally competitive and a responsible steward of the environment.

These projects address Roadmap objectives outlined by industry in the areas of Products and Markets, Materials Technologies, Manufacturing Technologies, and Environmental Technologies. As illustrated in Exhibit 8, Program funding has been distributed across all four of these Roadmap areas. This portfolio of research is also addressing OIT's key energy performance measures including yield improvement and scrap reduction, melting efficiency, and environmental benefits.

The remainder of this section lists currently funded research projects by Roadmap area. Summaries of projects currently in the portfolio are found in Appendix C.

Exhibit 8



<u>Products and Markets</u> - The Program is supporting projects which will enable metal casters to develop the technical capability to respond to changing casting requirements, techniques and trends in the industry. For example, it is researching thin section / thin wall castings to address the need for lighter weight, higher strength cast components in automobiles. It is supporting research to perform microstructural evaluations of a range of casting materials to evaluate and better realize their full potential. It is funding the development of modeling tools to improve die design, and reduce up-front costs in die manufacturing. Current projects in this area are:

- *Development of a fatigue properties database for use in modern design methods*
- *Gating of aluminum permanent mold castings*
- *Mechanical properties structure correlation for commercial specification of cast particulate metal matrix components*
- *Systematic microstructural corrosion performance evaluation of N-3MN and CK-3MCUN high molybdenum stainless steel*
- *Thin section steel castings*
- *Thin wall iron castings*

Materials Technologies - The Program is supporting research to improve the variety, integrity and performance of cast metal products. This research is helping to develop a better understanding of the casting characteristics, and mechanical and physical properties of casting materials. These include aluminum alloys, gray and ductile iron, lead-free copper alloys, magnesium and others. This research is also improving the quality and availability industry-wide of materials data. Current projects in this area are:

- *Clean, Machinable, Thin-Walled Gray and Ductile Iron Casting Production*
- *ZCA-9 Creep Resistant Alloy Development*
- *The Effects of Externally Solidified Product on Wave Celerity and Quality of Die Cast Products*
- *The Development of Surface Engineered Coatings for Die Casting Dies*
- *Age Strengthening of Gray Cast Iron - Phase III*
- *Heat Treatment Procedure Qualification for Steel Castings*
- *Casting characteristics of aluminum die casting alloys*
- *Design parameters for lead free copper based engineering alloys*
- *Die materials for critical applications*
- *Enhancements in magnesium die casting die life and impact properties*
- *Impurity limits in aluminum bronzes*
- *Predicting pattern tooling and casting dimensions for investment casting*
- *Process parameters for lead free copper based engineering alloys*

Manufacturing Technologies - The Program is supporting research on advanced manufacturing technologies and processes to improve the competitiveness of the industry and to enhance energy efficiency in metal casting processes. For example, the Program is supporting cost-shared research to develop and apply qualitative visualization tools for die design; extend the life of permanent molds for aluminum permanent mold castings; analyze risering techniques and methods for improving yield for steel casters; and identify lost foam process control procedures. The Program also is supporting research to analyze casting processes and to develop a better understanding of the cause of casting defects and methods to reduce or eliminate those defects. Current projects in this area are:

- *Sensors for die casting*

- *Effect of die design and dimensional features on thermal fatigue cracking of die cast dies*
- *Understanding the relationship between filling pattern and part quality in die casting*
- *Clean cast steel technology*
- *Optimization of composition and heat treating of die steels for extended lifetime*
- *Energy consumption in die casting operations*
- *Computer modeling of shot sleeves*
- *Investment shell cracking*
- *Ergonomic improvements for foundries*
- *Advanced lost foam casting technology - Phase V*
- *Conservation R&D /Yield improvement in steel castings (Yield II)*
- *Determination of residual stress and softening effects on die life*
- *Die materials for critical applications and increased production rates*
- *Effects of applied pressure during feeding on the fatigue properties of critical cast aluminum alloy components*
- *Heat transfer at the mold/metal interface in permanent mold castings of aluminum alloys*
- *Mold materials for permanent molding of aluminum alloys*
- *Optimization of squeeze casting processes for aluminum alloy parts*
- *Qualitative reasoning for additional diecasting design applications*
- *Re-engineering casting production systems*
- *Semi-solids metals processing consortium*

Environmental Technologies - Through cost-shared research in environmental technologies, the Program is enabling industry to identify methods to enhance the cleanliness of metal casting processes, increase both pre- and post-consumer recycling, and explore ways to reduce and eliminate waste streams.

- *Non-incineration treatment to reduce benzene and VOC emissions from green sand molding systems*
- *Steel foundry refractory lining optimization*

Appendix C provides brief summaries for each of the current projects in the Metal Casting Industry of the Future research portfolio by Roadmap area. Although projects are listed by the primary Roadmap that they address, some projects relate to multiple Roadmap categories. For example, the project "Energy Consumption in Die Casting Operations" addresses the Manufacturing Technologies section of the Roadmap by investigating methods to improve energy efficiency in die casting manufacturing processes. However, it simultaneously relates to the Environmental Technologies section of the Roadmap by addressing important environmental requirements facing the industry.

METAL CASTING IMPACTS & ACCOMPLISHMENTS: 1999

The Metal Casting Industry of the Future Program posted a number of important accomplishments during 1999. The Program's annual solicitation for competitive cost-shared research proposals resulted in seventeen awards. The ensuing research projects will make important contributions to ongoing efforts to address Vision targets and national energy efficiency goals. The Program's portfolio of research projects continued to make important progress in addressing Vision and Roadmap goals. Technologies resulting from this research continue to be adopted by industry. The following section describes highlights from 1999 including highlights for the partnership as well as significant research accomplishments.

Partnership Highlights

In 1999, the Metal Casting Industry of the Future made important accomplishments in the areas of technology transfer, partnership strengthening, and resource leveraging. Examples of these accomplishments include:

New Project Awards

- Seventeen research proposals were awarded during 1999. They are listed in Exhibit 9. In making these awards, new research organizations were added to the long list of research performers participating in OIT's metal casting research. These include: Colorado School of Mines, International Lead Zinc Research Organization, and Tri-State University.

Education

- It has been said that the best form of technology transfer is the education of today's students. The availability of a well-trained labor force in the U.S. metal casting industry has been one of the industry's top priorities for the past three years.[7] Because of the importance of education to the U.S. industrial base, the Metal Casting Industry of the Future places a strong emphasis on university-based research. Program-funded research is performed at nearly 20 universities across the U.S. U.S. students are being introduced to cutting-edge technology and materials research critical to the future health of the U.S. economy. In addition to successfully guiding well-trained students to productive careers in the industry, this approach has the double benefit of accessing the resources of some of the leading metal casting expertise in the country. The involvement of universities is resulting in the education of tomorrow's metal casting industry leaders -- education in the advanced technologies, materials, and processes that will be vital to the future competitiveness of the industry.

---

[7] "Outlook 2000: On the Rebound," *Foundry Management & Technology*, December 1999, p. 21.

Exhibit 9
FY 1999 Metal Casting Research Awards

Products & Markets	
Development of a Fatigue Properties Data Base for Use in Modern Design Methods	Climax Research Services
Material Technologies	
Clean, Machinable, Thin-Walled Gray and Ductile Iron Casting Production	University of Alabama at Birmingham
ZCA-9 Creep Resistant Alloy Development	International Lead Zinc Research
The Effects of Externally Solidified Product on Wave Celerity and Quality of Die Cast	Ohio State University
The Development of Surface Engineered Coatings for Die Casting Dies	Colorado School of Mines
Age Strengthening of Gray Cast Iron – Phase III	Tri-State University
Heat Treatment Procedure Qualification for Steel Castings	Pennsylvania State University
Manufacturing Technologies	
Sensors for Die Casting	Hayes-Lemmerz Technical Center
Effect of Die Design and Dimensional Features on Thermal Fatigue Cracking of Die Cast	Case Western Reserve University
Advanced Lost Foam Casting Technology – Phase V	University of Alabama at Birmingham
Understanding the Relationship Between Filling Pattern and Part Quality in Die Casting	Ohio State University
Clean Cast Steel Technology	University of Alabama at Birmingham
Optimization of Composition and Heat Treating of Die Steels for Extended Lifetime	Case Western Reserve University
Energy Consumption in Die Casting Operations	Ohio State University
Computer Modeling of Shot Sleeves	Ohio State University
Investment Shell Cracking	Tri-State University
Ergonomic Improvements for Foundries	Iowa State University

Metal Casting Technology Showcase

- OIT has recently begun implementing technology showcases as a strategy for communicating its diverse portfolio of research and technical assistance. Showcases also demonstrate the tangible improvements in plantwide energy efficiency and productivity that are possible through IOF partnerships. One company that has been an active partner in the IOF strategy is Lester Precision Die Casting. As stated by Joe Ponteri, President and CEO of GMTI (Lester's parent company) they decided to become involved as a way to "...leverage technology for commercial use".

The benefits of this partnership were demonstrated in November 1999 when the Metal Casting Program, NADCA and Lester Precision Die Casting showcased the state-of-the-art in die casting technology at Lester's Twinsburg, Ohio facility. This facility is one of the most advanced die casting plants in North America with automated pour, cast, extract, cooling and trim cells with a just-in-time plant layout. Over a 4-day period, Lester Precision Die Casting welcomed over 300 guests to its Twinsburg facility. On November 4th alone, 180 invited guests attended the Showcase: they include representatives from NADCA, 1 Congressional and 2 State Senatorial offices, regional and local Economic Development offices and others IOF industry leaders interested in future showcases. The diverse audience also included metal casters from around the U.S. as well as university and national laboratory researchers. In welcoming the guests, a letter from Energy Secretary Bill Richardson stated that "Americans are increasingly aware of the importance of energy conservation and global competition. Organizations such as NADCA play a special role in translating both of these concepts into reality...The entire Nation benefits through the energy efficiency and technology results derived from this program." The highlight of the Showcase was the opportunity to see first hand how Lester Precision Die Casting has been able to improve its operations by applying the results of OIT funded research and technical assistance. Through plant tours and poster presentations, hundreds of guests were shown how Lester is using the results of program-funded research to make significant improvements in die casting operations. Technologies showcased at the event started at the beginning of the process through alloy development, die design, die coating, and die material. In addition, the success of OIT's Integrated Delivery strategy in achieving plant-wide energy savings was highlighted through illustrations of the range of energy efficiency services and technical assistance available from OIT.

Awards, Recognitions and Presentations

- Harrison Steel Castings Company received the Iron and Steel Society's (ISS) Electric Furnace Conference 1999 Charles W. Briggs Award for its paper titled "*Acid steel making practice changes and results*". This work is a result of the DOE and CMC sponsored metalcasting research on Clean Steel at the University of Alabama (UAB)

- The success of the Metal Casting Industry of the Future partnership was recognized several times during 1999. For example, on November 3, 1999 NADCA presented a *Special Recognition Award* to DOE on behalf of the die casting industry. The award was "in recognition of the dynamic partnership that is working to shape our future and the Nation's."

- Members of the IOP and CMC volunteered their time to give a number of speeches on the IOF strategy and metal casting research accomplishments. These included speeches in the U.S., Canada and the United Kingdom.. For example:

    - Raymond Monroe, the Executive Director of the SFSA and the 1999 Executive Director of the CMC, gave a presentation on the Metal Casting IOF approach at the International Casting Conference held in England in September 1999. Later characterized as "the dream of those in industry from other countries"[8] the Metal Casting IOF was highly acclaimed by those in attendance and seen as a model for other countries.

- Dr. Raymond Donahue, Senior Director of Advanced Materials and Foundry Technology at Mercury Marine and a member of the Metal Casting Industrial Oversight Panel, spoke at conferences in Canada and elsewhere on the Metal Casting IOF partnership. In addition, he provided valuable insight on forward-looking metal casting industry research needs to the National Materials Advisory Board Study on Materials Technologies for Process Industries.

- Harry Ward, a member of the Metal Casting Industrial Oversight Panel, spoke at an Inventions and Innovation Conference in Sun Valley, Idaho in May 1999. He communicated not only the breadth of research activities and partnership opportunities available in the Metal Casting Program but the entire portfolio of OIT's technical and financial assistance.

Outreach and Technology Transfer

- In 1999, the Program continued to increase the number of industry partners participating in cost-shared research. Current participation is nearly 250 companies from 32 states. This broad participation is providing a direct avenue for dissemination of research results.

- In 1999, the International Energy Agency, Centre for the Analysis and Dissemination of Demonstrated Energy Technologies (CADDET) selected to highlight the Metal Casting Program's Lost Foam Technology Research in a CADDET brochure. The brochure describes in detail the many benefits of the lost foam casting process and uses the experiences of Mercury Marine in Fond du Lac, WI as an example of how industry is benefitting from the research results.

- In 1999, the number of articles on program-funded research and program activities more than doubled to over 25. These include articles in industry journals and newsletters such as *Cast Metal Review*, *Die Casting Engineer*, *Engineered Casting Solutions, Foundry Management & Technology*, and *Modern Casting*. Examples of recent articles include:

  - Research in Action: Die Casting Technology Showcase (Die Casting Engineer / January/February 2000)
  - Mechanical Properties of A356 Squeeze and A357 Semi-solid Castings (Die Casting Engineer / November/December 1999)
  - Research in Action: Squeeze Casting and Semi-solid Metal Processing Die Casting Engineer / November/December 1999)
  - SFSA Eyes Future Markets, Re-Engineering Present Systems (Modern Casting, November 1999)

---

[8] "NADCA Participates in International Casting Conference in England", William A. Butler, *Die Casting Engineer*, January/February 2000.

- Closed Loop Manufacturing and Rapid Tooling Improve Die Cast Die Quality, Reduces Lead Times (Die Casting Engineer)
- Total Product Optimization via Lost Foam Casting (Engineered Casting Solutions, Winter 1999)
- Ergonomics - A Neglected Science (Foundry Management & Technology / July 1999)
- ‘Shop-floor’ Process Controls for Lost Foam (Modern Casting / May 1999)
- Insight Exchanged on Lost Foam Process Controls and Capabilities (Modern Casting / January 1999)

Information also is available through OIT fact sheets and program reports. These are available on the OIT website at <www.oit.doe.gov> and from the OIT Clearinghouse at (800) 862-2086.

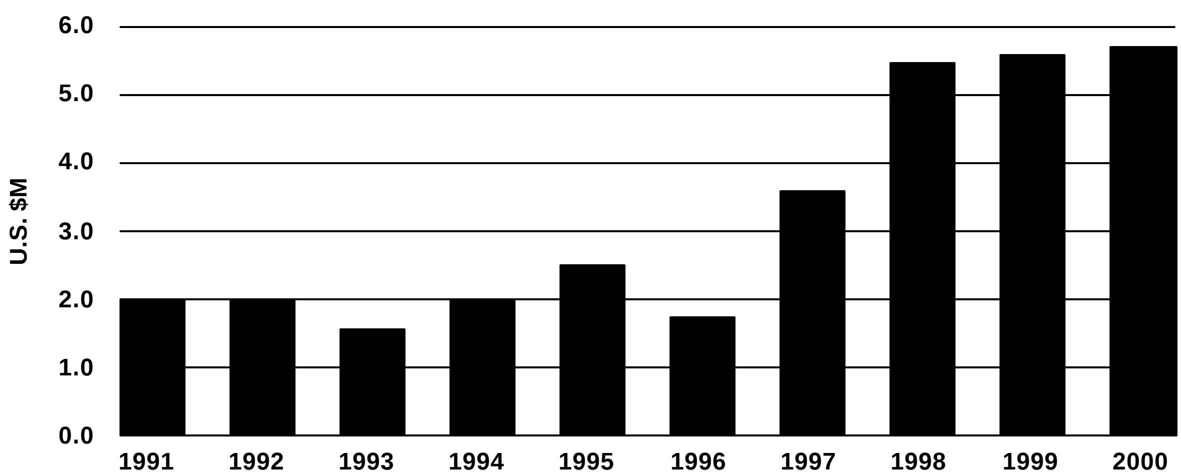
Leveraging Resources

< The program continues to maximize limited resources to co-fund high impact metal casting research. Along with industry cost-share requirements, the program leverages technical expertise from industry and academia as well as other research programs. Program funding is shown in Exhibit 10.

Exhibit 10
Metal Casting Program Funding

Leveraging Resources

All research funding requires broad application to industry as well as broad industry participation and cost-share. With 40 cost-shared projects involving 20 universities and labs, and nearly 250 companies, the program is leveraging vital resources for research.



Funding Support for Metal Casting Research & Development through DOE’s Office of Industrial Technologies

Energy and Environmental Profile

< The Program published an *Energy and Environmental Profile of the U.S. Metal Casting Industry* in September 1999. Copies can be obtained from the OIT Clearinghouse at (800) 862-2086.

Technical Research Accomplishments

The Metal Casting Industry of the Future R&D portfolio made important contributions to industry's Roadmap priorities as well as OIT's energy performance metrics during 1999. For example, advances continue to be made to improve control over the lost foam casting process. In steel foundries, techniques to significantly increase yield are being developed, and practices to improve the cleanliness of steel castings continue to be identified. Metal casting research is improving the ability of designers to improve the quality of casting design via computer-based tools requiring fewer plant trials. Research is helping the industry to better understand and improve the mechanical properties of alloys. This is enabling lighter weight, higher strength castings as well as dramatic reductions in scrap. Advances in manufacturing processes and control technologies are improving productivity and yield improvement throughout the casting industry. Some examples of recent research accomplishments include:

< **Consistent Casting of High Strength Ductile Iron, Climax Research Services** - This research is helping to improve control over nodule size and distribution using late-stream inoculation. Consequently, design strengths used for ductile iron castings can be raised -- leading to light weight iron castings. This research will enable greater application of ductile iron casting for components in automobiles and other transportation applications.

< **CastView, Ohio State University** - *CastView*™ is a PC-based modeling program for die casting flow simulation. It is based on a qualitative analysis of part geometry which yields extremely fast analysis times. This visualization tool is being used in the design stage to evaluate candidate gate, vent and overflow locations and to quickly compare candidate designs in order to select viable designs for consideration. It assists in reducing die try-out iterations, thereby reducing development lead times and scrap associated with die try-outs. *CastView*™ is now available commercially from NADCA. NADCA has distributed over 600 demonstration copies.

< **Mechanical Properties of Squeeze and Semi-solid A356, Case Western Reserve University** - A database of tensile, fatigue, toughness and impact properties for A356 aluminum produced by the squeeze and semi-solid casting processes was established. Properties and photomicrographs were incorporated in the manual, *NADCA Product Specifications Standards for Die Castings Produced Semi-Solid and Squeeze Cast Processes*.

< **Clean Metal Casting**, **Worcester Polytechnic Institute** – To improve melt cleanliness assessment technology, WPI has developed a standardized Reduced Pressure Test that has been endorsed by AFS as a recommended practice. In addition, WPI has developed a melt cleanliness sensor based on the principles of electromagnetic separation. The sensor is being commercialized by an industrial partner. In terms of melt contamination avoidance, WPI has developed environmentally friendly fluxes that do not contain fluorine; these fluxes will be soon commercialized by an industrial partner.

< **Re-engineering Casting Production Systems - Iowa State University -** The steel casting industry suffers from very high work in progress levels, contributing directly and indirectly to higher energy usage. Data on material movement has been collected and analyzed from in nineteen foundries and improved layout designs have been proposed. Six foundries have committed to make changes to their existing equipment layouts. In one foundry the relocation of a piece of equipment by 200 feet shows a potential to save 1500 miles of material movement over one year.

< **Thin Wall Castings - Penn State University -** Current limits on the wall thickness of sand castings is approximately 6mm. This limit is associated with the manufacturing techniques related to mold and core dimensional control. This research is investigating how to produce designs for thinner wall castings that takes advantage of the mechanical properties of steel -- specifically, carbon and stainless steel. Results so far have shown that it is possible to make both of these alloys fill a length of 20" for wall thicknesses of 4mm, this is well beyond the typical limit for 6mm which is usually stated as 12".

< **Study of Aluminum Alloy-Microstructure-Performance Interaction, Worcester Polytechnic Institute** - The research from this project showed that high strength levels were achieved with higher levels of magnesium, eliminating the need for heavier, thicker-wall castings. In one automotive casting, this translated into a weight savings of 0.2 pounds per part, or a 7% weight savings. The success of these findings is setting a precedent among die casters for thinner, light-weight designs. This is leading to significant energy savings through reduced alloy and melting requirements not to mention the improved fuel economy due to lighter weight automotive parts.

Information on research accomplishments is regularly made available through the CMC in its newsletter *Cast Metal Research Review,* trade journals, technical reports, the DOE website (www.oit.doe.gov), seminars, conferences and expositions.

These research results are helping the industry to improve its competitiveness in the U.S. and world markets while meeting increasingly demanding requirements for light-weight, high-strength, dimensionally accurate, complex castings. Simultaneous progress is occurring to improve yield, reduce scrap, and improve melt efficiency thereby improving energy efficiency.

Making Progress on Energy Metrics

All DOE-funded metal casting research must address specific goals of the DOE and OIT -- including improvements in energy efficiency. Each year, the Office of Industrial Technologies analyzes the energy benefits of its Programs and of specific research projects. The results contribute to DOE's annual reporting requirements under the Government Performance and Results Act (GPRA) of 1993.

To help assess how well Program-funded research is addressing energy efficiency goals the Program identified three specific Performance Measures:

- Yield Increases and Scrap Reduction
- Melting Efficiency Increases
- Environmental Benefits

Exhibit 11 briefly describes the Program's progress in responding to these performance measures. These selected projects shown are targeting greater competitiveness and productivity in the industry by increasing melting efficiency, increasing yield, and reducing scrap. In turn, they are improving energy efficiency in the industry by reducing energy requirements in melting.

Exhibit 11
Progress on Energy Performance Measures

Performance Measure	Selected Research Progress
Yield Improvement/Scrap Reduction - Melting is the most energy intensive phase of the metal casting process. Through yield improvements and scrap reduction, less melting/remelting is required per unit of production. Both cases increase energy efficiency in metal casting operations. The Metal Casting program is co-funding research to assist industry achieve 10% combined yield increases and scrap reduction by 2020 .	• **Lost Foam** - Researchers at the Univ. of Alabama - Birmingham, developed an instrument to measure the gas permeability of pattern coatings. Gas permeability controls the flow of metal into the pattern cavity and has a dominant effect on casting surface quality. This development is already helping to reduce scrap among lost foam casters. For example, applying new coating and liquid permeability procedures in one aluminum foundry resulted in its reducing its weekly scrap rate from 5.5% to 0.25% over a three-month period. Another foundry realized a scrap savings of $135,000/month on one part by optimizing air permeability and absorptive characteristics of the coating.[9] C **Yield Improvement in Steel Foundries** - Research at the Univ. of Iowa is determining factors which influence casting yield in steel foundries. New feeding and risering rules are being developed and unconventional techniques are being simulated to improve yield and thereby reduce scrap. The objective is to improve casting yield by 10% to 25%. Moreover, the ability to reduce the size and number of riser required to produce quality castings will help to reduce scrap in the steel foundry industry. Some rules-of-thumb are already being used and are resulting in a 50% improvement in feeding distance and improvements to risering of castings. C **CastView** - *CastView*™ simulation software was used to identify design improvements for a particular part. Resulting modifications led to a 20% scrap reduction and an increased production rate from 50 to 60 parts per hour and 20% more time between maintenance cycles. The energy savings for that one part alone was about 4.8 billion Btu per year. In another example, a die caster reports that the thickness information provided by the model was used for the placement of cooling lines in the die. The result was the production of acceptable castings, and hence, a success.[10] It is now available commercially. C **Macro-inclusions Atlas** - Reducing macro-inclusions can result in energy savings by reducing remanufacturing requirements. It was developed by Carnegie Mellon to assist foundries reduce the incidence of macro-inclusions. It permits analysis of the chemistry and size of problematic inclusions to determine the potential sources of macro-inclusions and to identify measures to reduce their occurrence.
Melting Efficiency - Melting accounts for approximately 55% of process energy costs. Improving efficiency in melting helps to reduce melting requirements and therefore energy consumption. Melting efficiency is gained through improvements in technologies directly impacting melting energy use. The Metal Casting Program is co-funding research to improve melting efficiency that will achieve an estimated 2% (0.005 quad) energy savings industry-wide by 2020.	C **Intelligent Control of the Cupola Furnace** - A collaborative project between Idaho State University, the AFS, INEEL, and Albany Research Center investigated the application of intelligent control methods. This resulted in the development of automatic control technology to lower cupola material and processing costs and to improve quality. The basis of this control technology is a comprehensive mathematical model enabling advanced process control and optimization. Energy and performance improvements result due to improved refractory performance, improvements due to oxygen enrichment, secondary combustion of natural gas, and melt zone expansion. Efficiency improvements of 5% are considered reasonable.[11] A 5% reduction in coking coal also is anticipated. The software is available through AFS. < **Study of Aluminum Alloy-Microstructure-Performance Interaction, Worcester Polytechnic Institute** - This project is developing a better understanding of the effects of various alloying elements on the properties of aluminum die casting alloys. It shows that high strength levels were achieved with higher levels of magnesium., eliminating the need for heavier, thicker-wall castings. In one automotive casting, this translated into a weight savings of 0.2 lbs. per part, or a 7% weight savings. The success of these findings is setting a precedent among die casters for thinner, light weight designs. This is leading to significant energy savings through reduced alloy and melting requirements not to mention the improved fuel economy due to lighter weight automotive parts. C **Energy Efficient Melting Practices** - Foundry energy analyses identified measures for improving energy efficiency in melting among other practices. This work, conducted in conjunction with NADCA and L.E. Griffith Associates, resulted in the identification of best practices and emerging technologies for energy efficiency, and energy savings recommendations. A manual, *Energy Use in the Diecasting Plant*, and an accompanying model was developed and is available through NADCA. Measures to improve efficiency in melting were identified. These include melting and holding furnace efficiency tests which will generate an estimated 5% efficiency improvement. Also, utilizing waste gases to preheat charge materials can significantly reduce energy requirements in melting. For example, up to one-third of the energy required for melting aluminum can be saved by preheating the aluminum to 400°F utilizing waste heat.[12]

---

9 Source: “Today’s Lost Foam Technology Differs from Yesteryear”, *Modern Casting*, April 1997, p. 32

10 Source: *Cast Metal Research Review*, Spring 1999.

11 Source: American Foundrymen’s Society.

12 Source: *Die Casting Engineer*, “Energy Conservation in Illinois Die Casting Facilities”, p. 18, November/December 1997.

Performance Measure	Selected Research Progress
Environmental Benefits - Virtually all of the research supported by the Metal Casting Program generates direct and indirect environmental benefits for the foundry industry. These are through energy savings and emissions reductions, scrap reduction, reduced disposal requirements and other measures. Research co-funded by the Metal Casting Program seeks to reduce environmental emissions from casting operations by 12%.	C **Reducing VOC and Benzene Emissions** - Green sand foundries are under increasing pressure to reduce benzene and volatile organic carbon (VOC) emissions during pouring, cooling and shakeout. Conventional incineration systems to treat stack gases are expensive to operate and difficult to maintain. Alternative pollution prevention strategies must be developed to comply with ever more demanding air quality requirements. Full-scale plant trials at green sand foundries have shown that simple non-incineration Sonoperoxone™ (SP) treatment systems or a combination of Sonoperoxone™ Plasma (SPP) treatment can significantly reduce emissions. In SP and SPP treatment systems, sand system baghouse dust is passed through a water slurry that has been pre-conditioned with ozone, hydrogen peroxide, and sonification/plasma treatment. Research is characterizing the behavior of VOC release, VOC adsorption, and VOC destruction for green sand systems as a function of temperature and SP/SPP treatment intensity, in a manner that facilitates lower VOC emission and higher quality metal castings. C **Alternative Granular Molding Media** - Silica sand for foundry use is inexpensive, readily transported and widely available. As a result, it is universally used. However, the disposal of waste foundry sand has become a high cost for the industry ($180 per cubic yard if contaminated by lead). In addition, phase changes which occur in the silica structure on heating and cooling cause thermal breakdown of the sand into smaller unusable fractions. This increases the tonnage of sand for disposal. The Program funded research to identify materials that are readily available as alternatives to silica sand. One of the media tested was synthetic mullite. Synthetic mullite requires less energy from the compactor to flow into the cavities. In addition, the media's thermal expansion is quite low – reducing the production of unusable fractions destined for disposal. This media has been claimed to be "one of the most significant advancements in lost foam since unbonded sand was patented in 1964".[13]

[13] Source: *Modern Casting*, "American Foam Cast: A Young Foundry Entrepreneur's Field of Dreams", September 1998, p. 47.

Appendix A
Metal Casting Vision & Roadmap

Appendix A
Metal Casting Vision & Roadmap

The U.S. Congress enacted the Department of Energy Metal Casting Competitiveness Research Act of 1990 (Public Law 101-425, 104 Stat. 915, 15 U.S.C. §5301-09) to improve the competitiveness and energy efficiency of the U.S. metal casting industry. The Act required the Secretary of Energy to establish a Metal Casting Competitiveness Research Program for the purpose of performing and promoting the performance of research and development on issues related to the technology competitiveness and energy efficiency of the U.S. metal casting industry. Under P.L. 101-425, the Program made significant contributions in the technical understanding of metal casting processes, manufacturing technologies and materials.

The metal casting industry established a vision for the future in *Beyond 2000: A Vision for the American Metalcasting Industry*. The Vision outlines specific goals for the industry over the next 20 years. Research being funded through the Metal Casting Industry of the Future is helping to achieve these industry goals. Simultaneously, this research is helping to achieve national energy efficiency goals of the U.S. Department of Energy and the Office of Industrial Technologies. As stated in its Strategic Plan, major goals of OIT are:

> *"A 25 percent improvement in energy efficiency and 30 percent reduction in emissions for the vision industries by 2010."*

> *"A 35 percent improvement in energy efficiency and 50 percent reduction in emissions for the vision industries by 2020."*

The Strategic Plan states that "OIT will motivate and will assist industry to develop technology solutions to critical energy and environmental challenges..." thereby producing important national benefits. Through its partnerships with industry and open and competitive research solicitations, OIT is making significant progress in assisting industry to address these challenges.

Vision and Roadmap

The industry's 20-year Vision, *Beyond 2000: A Vision for the American Metal Casting Industry,* was developed by industry leaders including chief executive officers and presidents from the foundry, die castings, and foundry supply industries. The vision process was facilitated by the Office of Industrial Technologies. The Vision commits the metal casting industry to being:

< *the preferred supplier of net- or near-net-shape metal components,*
< *globally competitive,*
< *environmentally responsible,*
< *well capitalized and profitable,*
< *a source of challenging and well-paying careers,*

- *the world's benchmark for technology and innovation, and*
- *supportive of a strong supplier base.*

While Beyond 2000 identifies major needs of the metal casting industry, it is the *Metal Casting Industry Technology Roadmap* which outlines technology milestones needed to achieve Vision goals. The Roadmap represents the critical link between the broadly defined strategic goals contained in Beyond 2000 and the detailed research portfolio that will be pursued through industry-government partnerships. The Roadmap outlines pathways of near-term, mid-term and long-term research activities in four critical areas: Products and Markets; Materials Technologies; Manufacturing Technologies; and Environmental Technologies. Exhibit A-1 lists specific industry targets and research priorities in these four areas. The Metal Casting Industry of the Future annually solicits competitive, cost-shared research in these areas.

Exhibit A-1
Metal Casting Vision & Roadmap Goals[14]

TARGETS	INDUSTRY RESEARCH PRIORITIES
Products & Markets *-Recapture 25-50% of lost markets* *-Improve market share in current markets by 10%* *-Increase the rate of new market development*	• Transform foundries to tier-one suppliers. • Develop computer design tools to move from design concept to a design for manufacturing. • Develop methods to encourage/systematize concurrent engineering partnerships within the metal casting industry. • Develop ways to demonstrate the quality and value of castings. • Develop tools and technologies to reduce lead times in the metal casting industry.
Materials Technology *-Improving the variety, integrity, and performance of cast metal products*	• Develop quantitative relationships between alloy chemistries, properties and processing. • Establish standard methodologies for materials testing. • Develop a clean melting and remelting process. • Develop methods for fast, accurate, and non-destructive evaluation of ingot and as-cast chemistries and properties (particularly for ferrous castings). • Develop improved techniques to measure the acceptability of liquid metal prior to casting. • Develop a national initiative to foster interest in materials science and engineering.
Manufacturing Technology *-Reduce energy consumption 20% by 2020* *-Increase productivity 15%* *-Reduce average lead time 50%*	• Develop low-cost rapid tooling technology. • Improve tooling design to reduce the time to get castings to market. • Develop cost-effective and dimensionally accurate patternmaking processes for use in sand casting. • Improve the ability to produce size/dimension. • Develop smart controls and sensors for automation supervision. • Develop a systems approach to scheduling and tracking. • Figure out how die casting molds/dies actually fill. • Understand folds for aluminum lost foam casting. • Develop melting and pouring technologies that do not introduce gases to the process. • Develop a mathematical model that describes process control and can control the machine.
Environmental Technology *-Achieve 100% pre- and post-consumer recycling* *-Achieve 75% re-use of foundry by-products* *-Eliminate waste streams completely*	• Develop environmentally benign, dimensionally stable molding materials for sand casting. • Develop new uses for waste streams and/or new ways to treat wastes to make them more usable. • Develop emissions databases for foundries to use to educate regulators

[14] Additional industry priorities are in the areas of: 1) Human Resources (to attract sufficient talent to the industry; and to keep present employees current with latest technologies and techniques); 2) Profitability and Industry Health (to increase financial resources available to fund research and educational and marketing programs by 10%); and 3) Partnerships and Collaborations (to encourage partnerships and collaborations to combine the experience, resources, and knowledge of available public- and private-sector organizations).

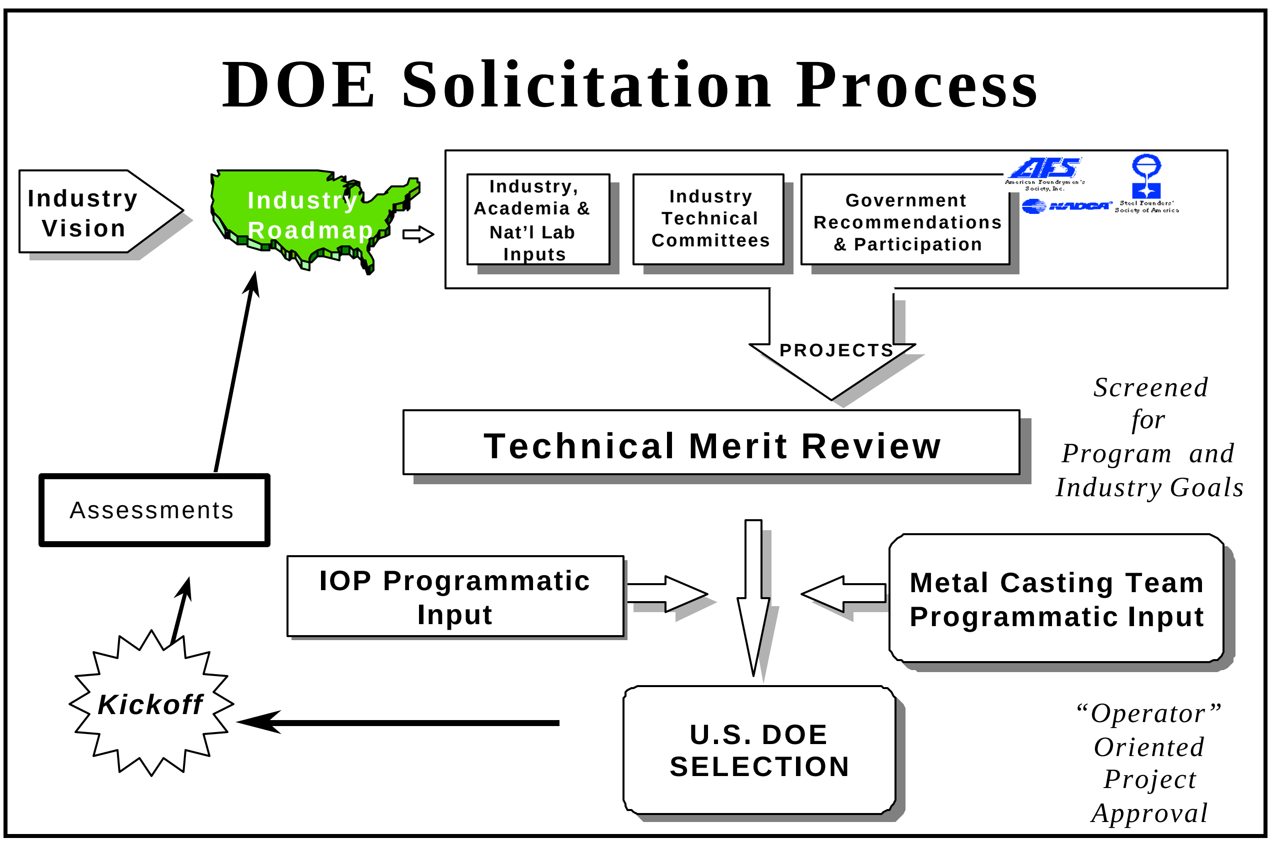
Competitive Solicitations For Metal Casting Research

All research solicitations through the OIT Metal Casting Industry of the Future are open and competitive. The solicitation and proposal review process is illustrated in Exhibit A-2. Solicitations are announced in trade society publications and meetings, the *Commerce Business Daily*, the OIT website and industry websites. DOE receives ad hoc and independent input from industry experts who are members of an Industrial Oversight Panel. The Metal Casting Team of DOE staff also provides independent input on proposals at this stage. Final review and selection is performed by the DOE source selection official.

Collaborations among industry, universities, and national laboratories are encouraged. All research proposals require cost-share. This commitment from industry helps to ensure industry involvement and that the research is aligned with industry's research priorities.

In emphasizing the importance of university-based research, the Program is helping to further the industry goal of enhancing education in the metal casting field of science and in building the human resources that the industry needs in the 21st Century.

Exhibit A-2



Appendix B
Current Metal Casting Research Partners:
By State

Appendix B
Current Metal Casting Research Partners: By State

Alabama
ABC Coke, Birmingham
American Cast Iron Pipe Co., Birmingham
Citation Corp., Birmingham
Citation Foam, Columbiana
Foseco, Bessemer
Mueller Corporation, Albertville
Southern Alloys, Sylacuagu
University of Alabama, Tuscaloosa
University of Alabama-Birmingham
Vulcan Engineering, Helena

Arizona
ME West Castings, Inc., Tempe

California
Alloy Tool Steel, Santa Fe Springs
ABI, Oakland
ISM, San Diego
Pacific Steel Casting Company, Berkeley

Colorado
Buhler, Denver
Colorado School of Mines, Golden
PCC ThixoForming, Inc., Longmont

Connecticut
Newton New Haven Co, North Haven

Georgia
Alumax, Norcross

Illinois
A. Finkl & Sons Co., Chicago
ABC Rail Products, Calera
ABC-NACO, Cicero
American Foundrymen's Society, Des Plaines
American Steel Foundries, Granite City
Arrow Aluminum Castings Co. Inc., Woodstock
Austin Associates, Quincy
Catepillar, Inc, Mapleton
Catepillar, Inc., Peoria
Chicago White Metal, Basenville
cmi novacast, inc., Elk Grove Village
CMM Services, Morton
FPM Heat Treatment, Elk Grove
General Kinematics, Barrington
H. Kramer & Co., Chicago
Heick Die Casting Corp., Chicago
Ingersoll Cutting Tools, Rockford
K&P Agile, Naperville
MAGMA Foundry Technologies Inc., Arlington Heights
Miller & Co., Rosemont
NACO, Downers Grove
NACO Technologies, Lombard
National Castings, Cicero
North American Die Casting Association, Rosemont
Primecast, South Beloit
Rio Tinto Iron & Titanium, Rosemont
Spartan Light Metal Products, Sparta
Steel Founders' Society of America, Barrington
Superior Graphite, Chicago
Wells Manufacturing, Woodstock

Indiana
ABC Rail Products, Anderson
Auburn Foundry, Auburn
Bohn Aluminum Corporation, Butler
Bosch Braking Systems, South Bend
Bremen Castings, Bremen
Chrysler Foundry, Indianapolis
Chrysler Corporation, Indianapolis
Cummins Engine, Columbus
Daimler Chrysler, Indianapolis
Dalton Warsaw, Warsaw
Dalton Kendallville, Kendallville
Electric Steel Castings Company, Indianapolis
Hard Chrome, Evansville
Harrison Steel Castings Company, Attica
Hiler Industries, LaPorte
Intat Precision, Rushville
Littler Diecast Corp., Albany
Maco Corp, Huntington
Matrix Technologies, Muncie
Ryobi Die Casting (USA), Inc., Shelbyville
Shenango, Terre Haute
Technalysis, Indianapolis
Tri-State University, Angola
Ultra-Cast, Peru
Wabash Alloys, Wabash

Iowa
Iowa State University, Ames
Keokuk Steel Casting, Keokuk
Sivyer Steel Corporation, Bettendorf
University of Iowa, Des Moines

Viking Engineering Cast Products, Cedar Falls

Kansas
Atchison Casting Corporation, Atchison

Kentucky
Carrollton Casting Center, Carrollton
Furness-Newburge, Inc., Versailles
Gibbs Die Casting, Henderson

Louisiana
Amite Foundry & Machine Inc., Amite
Carbo Ceramics, Iberia

Maryland
Concurrent Technologies Corp., Potomac
UES, Inc., Annapolis

Massachusetts
Aluminum Casting Research Laboratory Consortium, Galesburg
Kennedy Die Casting, Inc., Worcester
Wollaston Alloys, Inc., Braintree
Worcester Polytechnic Institute, Worcester

Michigan
A-CMI, Fruitport
AMCAST Automotive, Southfield
Ancast, Inc., Sodus
Applied Process Technologies, Livonia
Bay Cast, Inc., Bay City
Chem-Trend, Howell
Climax Research Services, Farmington
CMI-Michigan Casting Center, Cadillac
CMI-Tech Center, Ferndale
Delphi, Saginaw
Delta Resins & Refractories, Detroit
Dock Foundry, Three Rivers
Dow Chemical, Midland
EKK, Walled Lake
Ford Motor Company, Dearborn
Ford Electronics Division, Dearborn
General Motors Powertrain, Saginaw
General Motors, Bedford
GM Powertrain, Pontiac
Grand Rapid Aluminum Casting, Grand Rapids
Hayes-Lemmerz International, Ferndale
Hickman Williams, Livonia
Howmet Corp., Whitehall
ITT Automotive, Auburn Hills
LECO, St. Joseph
Lucas Varity, Livonia
Metalloy Corporation, Hudson
NEMAK, Southfield
Niles Chemicals, Niles
PNGV,
Premier Tool & Die Cast Corporation, Berrien Springs
Prince Machine Co., Holland
Simpson Industries Inc., Jackson
SPX/Contech, Portage
UBE Machinery, Ann Arbor
University of Michigan, Ann Arbor
West Michigan Steel Foundry, Mukegon
XPS Cortech, Portage

Minnesota
Nicollet, Minneapolis
Progress Casting Group, Plymouth
Tool Products, Minneapolis

Mississippi
Mississippi State University, Mississippi State
Southern Cast Products, Meridian

Missouri
AB Chance Co., Centralia
Carondelet Corporation, Pevely
Die Makers, Monroe City
Missouri Steel Castings, Joplin
St. Louis Precision Casting Co., St. Louis
Stahl Specialty Company, Kingsville
University of Missouri, Rolla
Wellsville Fire Brick Co., Wellsville

New Hampshire
Claremont Foundry, Inc., Claremont

New Jersey
Howmedica Inc., Rutherford
Ingersoll-Rand, Phillipsburg

New York
Crucible Steel, Solvey
Eastern Alloys, Maybrook
Welding Research Council, New York

North Carolina
Consolidated Diesel, Whitakers
International Lead Zinc Research Organization, Research Triangle
Selee Corporation, Hendersonville
Southeastern Foundry, Greensboro

Ohio
ACM Coldwater, Coldwater
Ashland Chemical Co., Cuyahoga Heights
Blaze Technical Services, Stow
Brost Foundry Co., Brecksville
Brush Wellman, Cleveland

Buckeye, Columbus
Bunting Bearing Corp., Delta
Case Western Reserve University, Cleveland
Copeland Corp., Sidney
Crown Equipment Corp., New Bremen
CSM Industries, Cleveland
DCD Technologies, Cleveland
Electroalloys Corp., Elyria
Elkam Metals Co., Ashtabula
Empire Die Casting, Cleveland
Euclid Heat Treat, Cleveland
Fairmont Minerals, Chardon
Foseco, Cleveland
General Die Casters, Peninsula
Lester Precision Die Casting, Twinsburg
Lincoln Electric Co., Cleveland
Lindberg Heat Treat, Solon
Manoir Industries, Elyria
Mercury Machine, Solon
Ohio State University, Columbus
Precision Metalsmiths, Inc., Cleveland
Procast, Dayton
Sawbrook Steel Castings Co., Lockland
Southwest Steel, Cincinnati
Universal Energy Systems, Inc., Cleveland
Visi-Trak Corp, Cleveland
Wahl Refractories, Fremont
Willard Industries, Cincinnati

Oregon
Northwest Aluminum, Portland
PED Manufacturing Ltd., Oregon City
Varicast, Portland

Pennsylvania
Advanced Cast Products, Meadville
Alcoa, New Kensington
Apogee, Verona
Baker Refractories, York
Blue Ridge Pressure Castings, Lehighton
Colonial Metals Co., Columbia
Duraloy, Scottdale
Durametal Corp., Muncy
Esab Welding & Cutting Products, Hanover
Frog Switch Company, Carlisle
Latrobe Steel, Latrobe
McConway & Torley Corporation, Pittsburgh
North American Refractories, State College
Nova Precision, Auburn
Pennsylvania Foundry & Machine Company, Hamburg
Pennsylvania State University, College Park
Pennsylvania Steel, Hamburg
Premier Refractories & Chemicals, King of Prussia
Quaker Steel Castings, Reading
Quaker Alloy, Myerstown

South Carolina
Advanced Technology Institute, Charleston

Tennessee
American Magotteaux Intl., Pulaski
GM Saturn, Spring Hill
Harvard Industries, Ripley
MINCO, Inc., Midway
Oak Ridge National Laboratory, Oak Ridge
Teksid Aluminum Foundry, Inc., Dickson
University of Tennessee, Knoxville
Wheland Foundry, Chattanooga

Texas
GH Hensley Industries, Inc., Dallas
KO Steel Foundry, San Antonio
Southwest Steel, Longview
Styrochem Intl., Ft. Worth
Texas Steel, Fort Worth

Virginia
Intermet Technical Service, Lynchburg
Reynolds Metals Co., Richmond

Washington
Atlas Foundry and Machine, Tacoma
Spokane Steel, Spokane
Spokane Industries, Spokane
Varicast, Vancouver
Waupaca Foundry Co, Waupaca

West Virginia
Ormet, Wheeling

Wisconsin
American Colloid, Berlin
Badger Metal Technology, Menomonee Falls
Badger Mining, Berlin
Briggs & Stratton, West Allis
Brillion Iron Works, Brillion
Burden, Inc., Oak Creek
Falk Corporation, Milwaukee
Grede Foundries, Inc., Milwaukee
JL French Corporation, Sheboygan
Kohler Company, Kohler
Madison-Kipp Corp., Madison
Maynard Steel Casting Company, Milwaukee
Mercury Marine, Fond Du Lac
Milwaukee Steel, Milwaukee
Neenah Foundry Company, Neenah
Northern Stainless, Pewaukee
Outboard Marine Corp., Waukesha
Pelton Casteel, Milwaukee
Stainless Foundry & Engineering, Milwaukee
Starline Manufacturing Co, Inc., Milwaukee
University of Wisconsin, Milwaukee

Walkington Engineering, Cottage Grove
Waukesha Foundry, Waukesha
Waukesha Cherry Burrell, Delevan
Waukesha Fluid Hardening, Waukesha
Wisconsin Invest Cast, Watertown
Wisconsin Centrifugal, Inc., Waukesha
Wright Products Corp., Rice Lake

Appendix C

Current Metal Casting Research Projects and Partners: By Roadmap Area

Appendix C
Current Metal Casting Research Projects and Partners: By Roadmap Area

Manufacturing Technologies

Advanced Lost Foam Process Development Phase IV, University of Alabama - Birmingham - Lost Foam Casting has significant cost and environmental advantages and enables metal casters to produce complex parts. The process allows designers to consolidate parts, reduce machining and minimize assembly operations. It also allows foundries to reduce solid waste and emissions. This research has resulted in significant improvements in lost foam process controls. The objective of the continuation is to develop a data base for pattern degradation properties at typical metal velocities and temperatures. This data, along with coating and sand permeability and thermal property data, will be merged into a commercial fill/solidification code to describe the physical events of metal replacement of lost foam patterns and validated using real time x-ray and instrumented castings.

Advanced Cast Products	*Copeland Corp.*	*Nemak, S.A.*
American Foundrymen's Society	*GM Powertrain*	*Niles Chemical*
Ashland Chemical Company	*GM Saturn*	*Outboard Marine*
Austin Associates	*General Kinematics Corp.*	*Southeastern Foundry*
BMW AG, Germany	*Intermet Corporation*	*Stanton PLC*
Burden, Inc.	*Kohler*	*Styrochem International*
Briggs & Stratton	*MACO Corporation*	*UES ProCast Group*
Carbo Ceramics	*Mercury Marine*	*Volkswagen AG*
Caterpillar	*Montupet*	*Vulcan Engineering Company*
Citation Foam	*Mueller Company*	*Willard Industries*

Clean Metal Casting- Aluminum, Worcester Polytechnic Institute - The objective of this project is to develop a technology for a clean metal processing that is capable of consistently providing a metal cleanliness level fit for a particular application. The emphasis will be on non-ferrous metals, particularly aluminum casting alloys. Two classes of contaminants that prevail in molten aluminum are being studied: hydrogen and inclusions (oxides, carbides, etc.). methods to control process atmosphere using inert and reactive gases to reduce hydrogen absorption are being investigated. Alloying elements and supernatant cover media that may substantially reduce melt oxidation are also being considered. In addition, barrier coatings that interfere with in situ carbide formation will be researched.

Foseco	*Madison-Kipp Corp.*	*Stahl Specialty Company*
Hitchcock Industries	*Palmer Foundry*	
Kennedy Die Casting, Inc.	*Selee Corporation*	

Clean Steel, University of Alabama - Birmingham - The overall objective of the Clean Steel Program at UAB is to reduce scrap and improve casting product quality by removing or minimizing oxide defects. This program is currently being extended to Identify the metallurgical factors influencing machinability of steel and to gain an engineering understanding of the mechanism. In past years, research efforts were concentrated on macro-inclusion that break, chip or crack machine tool cutters and drills and cause productivity losses. Work to eliminate these led to optimizing pouring techniques including metal stream shrouding and ladle design, and evaluating in-mold devices such as filters and filter-flow control devices for their ability to reduce macro-inclusions. Current effort involves application of a computer model to simulate metal flows and identify the effects of flow conditions on casting quality. Methods of homogenizing the metal temperature in the ladle will also be evaluated. Research is also being conducted to determine sources of heat-to-heat variations in metal cleanliness. Foundry trials demonstrated that modifications of the furnace practice can improve the quality of steel castings produced from 30 to 40% in some cases.

American Steel Foundries	*Foseco-Morval, Inc.*	*Pelton Casteel*
Atchison Casting Corporation	*Harrison Steel Castings Company*	*Premier Refractories & Chemicals*
Dominion Castings LTD	*Keokuk Steel Castings, Inc.*	*Sawbrook Steel Casting Company*
Electric Steel Castings Company	*KO Steel*	*Steel Founders' Society of America*
Falk Corporation	*Maynard Steel Casting Company*	*Texas Steel Company*

Computer Modeling of Shot Sleeves, Ohio State University - During the first phase of this project, a variety of shot sleeves in commercial use were evaluated using two and three dimensional finite element models. Also, a shot sleeve test stand was constructed to experimentally determine appropriate heat transfer coefficients for the finite element models. Actual sleeve distortions have also been measured using the test stand. The objective of the current phase is to improve the usable life of shot sleeves, particularly larger diameter sleeves that experience premature failure in service at a high frequency. This will be done by developing a better understanding of temperature and mechanically induced strains existing in shot sleeves during service, through the use of computer models, and by the collection of related in-process shot sleeve data. The technical result of improved shot sleeve design and useful life translates into less die casting machine downtime, lower tooling costs, and improved casting quality. A by-product of improved casting quality would be a reduction in energy required per acceptable casting produced.

Briggs & Stratton	*North American Die Casting Association*	*XPS Cortech*
GM Bedford	*Visi-Trak Corp*	
Lester Precision Diecasting	*Walkington Engineering*	

Determination of Residual Stress and Softening Effects on the Life of Die Casting Dies, Case Western Reserve University - The objective of this research is to evaluate measurement methods and develop ways of reducing losses in die life caused by softening of the steel and build-up of residual stress. Researchers have identified and evaluated a portable hardness tester with adequate range and resolution for in-situ measurement of softening in dies. They also have mapped hardness in production dies, quantifying the softening effect and confirming substantial loss in hardness in the heat checked areas.

Badger Metals Tech.	*Harvard Industries*	*North American Die Casting Association*
CMI	*ITT Automotive*	*Universal*
Crown Equipment Corp.	*Lindberg*	

Die Materials for Critical Applications and Increased Production Rates, Case Western Reserve University - The goal of the study is to improve the quality and reduce the manufacturing cost of aluminum die casting in the U.S. A specific objective is to double the life of die casting inserts exposed to the most severe die casting conditions by testing, comparing and providing guidelines for selective use of high-alloy tool steels, refractory and other non-ferrous high temperature die materials, and diffusion coatings. This work will build on a prior and recently completed DOE-funded project at CWRU entitled "Effect of Composition and Processing on the Thermal Fatigue Resistance and Toughness of High Performance Die Steels".

A. Finkl & Sones	*Chem-Trend*	*FPM Heat Treatment*
Alloy Tool Steel	*CMI-Tech Center*	*Latrobe Steel*
Badger Metal Technology	*CSM Industries*	*North American Die Casting Association*
Brush Wellman	*DCD Technology*	

Effects of Applied Pressure During Feeding on the Fatigue Properties of Critical Cast Aluminum Alloy Components, Mississippi State University - This research is to determine the effect of applied pressure during feeding on the distribution, level, and morphology of porosity, and subsequently on the fatigue behavior of critical cast aluminum components. Many components used in safety-critical systems in automobiles and aircrafts, are of complex shape and lend themselves to casting to minimize costs. Many of the alloys used in these applications freeze over a long temperature range and are prone to dispersed porosity defects. Dispersed porosity in aluminum alloy castings has profound effects upon mechanical properties of engineered components produced this way. Both static properties (ductility, tensile strength, etc.) and dynamic properties (fatigue strength, and properties associated with the time dependence of fatigue crack initiation and growth) are affected. Although rigorous techniques of degassing and riser design can partly alleviate this situation, the effects of residual porosity are serious.

A-CMI, Michigan Casting Center	*CMI Novacast, Inc.*	*GM Powertrain*
American Foundrymen's Society	*Ford Motor Company*	*The Metalloy Corporation*
Bohn Aluminum Corporation	*Foseco*	

Effects of Die Design & Dimensional Features on Thermal Fatigue Cracking of Die Casting Dies, Case Western Reserve University- The goal of this research is to identify and evaluate the effect of design factors such as size and location of cooling lines, sudden changes in cross-section and sharp radii on the life of die casting dies. The study will provide die designers with computer tools that allow them to predict the thermal stresses in dies and a method to relate these stresses with thermal fatigue cracking. These tools can be applied towards mitigating or eliminating design related problems and their adverse effect on die life. The study will develop a new approach in design of dies for thermal fatigue resistance. This approach is designed to identify potential hot spots (thermal) and high stresses in the design by minimizing them by modifying the dimensions of the inserts and the location and size of the cooling lines. It includes 1) computer aided design of the die with all geometrical details, including location of cooling lines, 2) couple finite element modeling of flow/thermal/stress of the die, and 3) thermal fatigue immersion testing to determine the actual effect of the maximum design temperatures and stresses on the heat checking damage.

A. Finkle & Sons	*CSM Industries*	*Latrobe Steel Company*
Alloy Tool Steel	*DCD Technologies*	*Lester Precision Die Casting*
Badger Metal Technology	*FPM Heat Treatment*	*North American Die Casting Association*
Brush Wellman	*General Die Casters*	*Procast*
Chem-Trend	*Hayes-Lemmerz Tech Center*	*Thyssen*

Energy Consumption of Die Casting Operations, Ohio State University - The objective of this project is to examine energy consumption as a cost of die cast products. The use of life cycle assessment (LCA) to compare the environmental impacts of materials and energy inputs and waste outputs for various components for automotive, appliances, and electronic products is an emerging trend. Several companies will participate in this study and will supply information on energy and equipment.

GM Powertrain	*North American Die Casting Association*	*Premier Tool & Die Cast Corporation*

Ergonomic Improvements for Foundries, Iowa State University -Manual operations remain an important part of many metal casting operations, due to the diverse products produced. This diversity makes automation infeasible. Ergonomics is the science of fitting workplace conditions and job demands of the working population. This project will take a reactive and proactive approach to solving ergonomic problems which lead to poor product quality, poor productivity, and poor lead times. The purpose of this project is to introduce ergonomic thinking into the foundry industry. It will involve student training, mini-workshops and evaluations, and off-site assessments of process evaluations. Process improvements and ergonomic improvements will be identified. The project team will introduce improvements onto the foundry floor through training and workshops..

ABC-NACO	*Electric Steel*	*Southwest Steel*
American Magotteaux	*McConway and Torlay*	*Steel Founders' Society of America*
American Steel Foundries	*Sivyer Steel*	
Buckeye	*Southern Cast Products*	

Heat Transfer at the Mold/Metal Interface in Permanent Mold Casting of Aluminum Alloys, University of Michigan - The objective of this project is to evaluate heat transfer between mold and casting in permanent casting of aluminum alloys. Considerable energy savings can be achieved by more precise design of these castings. The design improvements require further understanding of the fundamentals of the process, in particular, interfacial heat transfer including the influence of gap formation and mold coatings, the stress and deformation of the solidifying castings, as well as the thermal and mechanical behavior of the mold. Modeling and experimental measurements will be made to provide a means for the foundry worker to define and predict multi-dimensional heat flow in permanent mold casting. The resulting design will allow production of castings with closer tolerances, improved properties, higher integrity, and lower weight.

AMCAST Automotive	*Concurrent Technologies Corp.*	*K&P Agile*
American Foundrymen's Society	*Delta Resins & Refractories*	*UES, Inc.*
CMI Tech Center	*Ford Motor Co.*	

Investment Shell Cracking, Tri-State University - This project will investigate methods to produce more reliable mold shell for investment casting. Recent developments in materials testing for structural ceramics and polymers will be adapted to ceramic shells and wax patterns used in investment casting. The project will include: 1) designing a standard test casting, 2) developing bench-scale tests for ceramic shells and wax (polymer) pattern materials, (3) applying these tests to production materials from participating foundry companies and correlating the results with observed defect occurrences, and 4) determining which process parameters can be used that most directly correlate with the results from bench-scale and participating foundries.

ABC-NACO	*Spokane Steel*	*Wisconsin Invest Cast*
Nova Precision	*Stainless Foundry*	*Wisconsin Centrifugal*
PED Manufacturing	*Steel Founders' Society of America*	

Mold Materials for Permanent Molding of Aluminum Alloys, Case Western Reserve University - This project is designed to extend the life of permanent molds for aluminum permanent mold castings, reduce the cost of permanent molds, and improve surface quality and soundness of aluminum permanent mold castings. It is a follow-on to die materials work being performed by CWRU on extending the life of die casting dies. The project will develop a quantitative procedure to estimate the expected mold life and mold cost. The project also will evaluate the effectiveness of different coating materials on the die to control the solidification rate of different sections or areas of the mold surface by affecting the heat diffusivity of that area.

Amcast Automotive	*CMI-Tech Center*	*St. Louis Precision Casting*
American Foundrymen's Society	*DCD Technology*	*Stahl Specialty Co.*
Arrow Aluminum Castings Co. Inc.	*Foseco, Inc.*	*UES Inc.*
Bohn Aluminum Corp.	*Grand Rapid Aluminum Casting*	
CMI-Michigan Casting Center	*Progress Casting Group*	

Optimization of Composition and Heat Treating of Die Steels for Extended Lifetime, Case Western Reserve University - The objective of this study is to obtain a 50% improvement in the life of die casting dies by compositional modifications and optimized heat treatment. This improvement could translate into a $500 million yearly savings in direct die costs. Much larger indirect savings are associated with prevention of production losses caused by die failures and machine down time. This subject has been studied at CWRU since the early 1960's, most recently in a project sponsored by DOE entitled "Effect of Composition and Processing on Thermal Fatigue Resistance and Toughness on Die Steels,". These previous efforts have been successful, resulting in the finding of a new type of die steel with al lower silicon and vanadium, and higher molybdenum content than the standard premium grade H-13 steel. Further improvement in the life of the die steels could be obtained by utilizing a rapid cooling rate from a somewhat higher austentizing temperature during the hardening process. An optimized EDM process in shaping dies was also demonstrated with practically no undesirable effects on the thermal fatigue resistence. The main objectives of this new 1-yr project are to 1) further evaluate the effect of controlled changes in steel chemistry on the resistance to heat checking, 2) verify the results of the laboratory tests with in-plant trials using production die casting machines.

Alloy Tool Steel	*DCD Technology*	*Latrobe Steel Company*
Badger Metal Technology	*FPM Heat Treatment*	*North American Die Casting Association*
Chem-Trend	*Hayes/CMI Tech*	

Optimization of Squeeze Casting Process for Aluminum Alloy Parts, Case Western Reserve University - Squeeze casting is a new and developing casting technology suitable for manufacturing light weight structural aluminum castings needed for the production of advanced components in applications such as the automotive industry. Because squeeze casting is a relatively new process, much work needs to be done to better understand the fundamentals of the process in order to optimize the variables. Fundamental heat and mass transfer principles will be applied to the squeeze casting process, with experimental work performed on an industrial scale 315 metric ton squeeze caster. Detailed experimental study of metal flow and heat transfer in the squeeze casting process and analyses of the relationships between the design of the part, the squeeze casting system, the processing variables, and the soundness of the castings will be carried out.

Blaze Technical Sensors	*Ford Motor Company*	*North American Die Casting Association*
CMI	*ITT Automotive*	*Nicollet*
DCD Technology	*Latrobe Steel Company*	*UBE Machinery*
Euclid Heat Treat	*Lindberg Heat Treat*	

Qualitative Reasoning for Additional Diecasting Design Applications, Ohio State University - This project builds off a previous effort developing Simple Visualization Tools, using CastView, to improve die design. The goal of this research is to develop design tools for die casting that can be used to promote the compatibility between the design and the die casting. Specific goals are to reduce part development lead time by at least 15% and to reduce tryout and setup time by at least 30%.

Chicago White Metal	*GM Powertrain*	*Prince Machine*
DCD Technologies, Inc.	*ITT Automotive*	*Ryobi*
EKK	*J.L. French*	*Spartan Light Metal Products*
Exco Engineering	*Madison Kipp*	*UES*
Ford Motor Company	*Magma*	*Walkington Engineering*
General Die Casters	*North American Die Casting Association*	*Wright Products*

Re-Engineering Casting Production Systems, Iowa State University - Castings are an inherently excellent choice for many applications, because of the ability of the process to directly create complex shapes. By making metal castings more affordable, the use of castings will be expanded, especially in the transportation sector. However, current foundries suffer from poor facility design and large work in process inventories. The problems especially occur in the casting finishing areas, which includes blast cleaning, riser removal, grinding, production welding and heat treatment. The problem is in part due to the labor intensive nature of the finishing processes. Typically, finishing accounts for 50% of the cost of production steel castings. The research effort at Iowa State University aims to decrease the costs of producing castings by improving the production systems used to produce them. The goal of the project is to develop solutions that are applicable to the entire foundry industry, and disseminate the results through technology transfer activities. Three significant issues have been identified in this work: 1) Current scheduling systems, manual or software developed are incapable of sequencing work through a production process where part size and quantity are constantly varying. This is particularly true of the steel casting industry which is frequently described as a jobbing operation. ISU have developed some scheduling software that takes account of these factors and it is being sent to industry for trials. 2) Plant layout tends to be viewed in a Awhere can I fit@ mode rather than determining the effect on process flow efficiency. 3) The amount of manual handling is excessive, this raises the question of how this affects the efficiency. This points to the need to examine the ergonomic aspects of manufacture.

Amite Foundry & Machine, Inc.
Bay Cast, Inc.
Carondelet Corporation
Claremont Foundry, Inc.
Durametal Corporation
Falk Corporation
GH Hensley Industries, Inc.
Harrison Steel Castings Company
ME West Castings, Inc.
McConway & Torley Corporation
Mercury Marine
NACO Technologies
Primecast
Sawbrook Steel Castings Co.
Shenango Industries, Inc.
Southwest Steel Castings Co.
Steel Founders' Society of America
Texas Steel Company
Varicast, Inc.
Waukesha

Semi-Solid Metals Processing Consortium, Worcester Polytechnic Institute - The research program will address fundamental technical issues of semi-solid metal processing and contribute to the development of a knowledge base for the commercial sector. The research will address fundamental technical issues of semisolid metal (SSM) processing and contribute to the development of a knowledge base for the commercial sector. Work will be conducted under three main tasks: 1) Material Characterization 2) Modeling and Simulation of Die Filling, and 3) Die Design

North American Die Casting Association
17 industry partners of the Semi-solid Metal Processing Consortium

Sensors for Die Casting, Oak Ridge National Laboratory - The use of aluminum alloy castings for automotive applications is rapidly increasing due to the need for weight savings leading to a reduction in fuel consumption and emission levels. The replacement of a ferrous component by an aluminum alloy component typically results in mass savings of 50%. The goal of this project is to evaluate and implement vibration sensors for machine diagnostics of die casting machines which will improve the quality and consistency of production castings made by the die casting industry. Emphasis will be placed on the application of commercially available sensors, and on their implementation in a robust and practical format that may be readily transferred to the die casting industry.

Briggs & Stratton
Chem-Trend
Littler Diecast Corp.
Kennedy Die Castings, Inc.
Newton-New Haven Co.
North American Die Casting Association
Prince Machine Corp

Understanding the Relationship Between Pattern Filling and Part Quality in Die Casting, Ohio State University - The objective of this project is to understand the phenomena involved in the filling of the die cavity and the relationships between fill parameters and part quality. The effects of gate geometry at part entry, gate velocity, and slow-to-fast shot acceleration on filling patterns in die casting, and ultimately part quality, will be explored. The results should produce a better understanding of the die filling phenomena under a variety of gate entry geometries, selected common cavity geometries, and gate velocities.

General Die Casters
GM Bedford
Lester Precision Die Casting
North American Die Casting Association
Walkington Engineering

Yield Improvement in Steel Castings, University of Iowa - The objective of the research is to investigate methods for improving yield in steel casting. Specific goals are: to develop techniques to improve yield on current practices by 10% while maintaining the same quality level; develop novel techniques to improve yield by 25% on a fully optimized casting system; and document the developed techniques, procedures and findings in manuals and reports to allow all steel casting producers to benefit. Current research is emphasizing 1) Conventional feeding and risering methods, 2) Unconventional yield improvement techniques, and 3) Case studies.

American Steel Foundries	*KO Steel Foundry*	*Shenango*
Atchison Casting	*Missouri Steel Castings*	*Stainless Foundry*
Bay Cast	*NACO*	*Steel Founders' Society of America*
Electric Steel	*Pacific Steel Casting Company*	*Texas Steel,*
Falk	*Pennsylvania Steel*	*Varicast*
Harrison Steel Castings	*Quaker Alloy*	*Waukesha Cherry-Burell*

Materials Technologies

Age Strengthening of Gray Cast Iron Phase III, Tri-State University - The research will further investigate the age-strengthening of gray cast iron. It appears that under specific conditions, aging can improve both machinability and strength. This research will identify and quantify the mechanism as well as develop techniques to speed the aging process allowing industry to utilize this phenomenon on a production basis.

ACM Coldwater	*Bremen Castings*	*Dock Foundry*
American Foundrymen's Society	*Dalton Warsaw*	*LECO*
Auburn Foundry	*Dalton Kendallville*	

Casting Characteristics of Aluminum Die Casting Alloys, Worcester Polytechnic Institute - This is a continuation of an existing project which resulted in a comprehensive database of alloy microstructures and mechanical and physical properties. The goal of this project is to evaluate the melting and casting characteristics of those alloys that were determined to be of optimum composition for each of the properties measured. WPI will evaluate alloys that represent both good physical and mechanical properties and then develop castability indices. The melting and casting characteristics to be considered include: quantity and type of sludge produced during melting, melt fluidity, tendency of the alloy to die sticking, and tendency of the alloy to hot tearing. The comprehensive data set that will result should enable metallurgists, die casters, and design engineers to fully exploit the potential of aluminum die casting alloys.

Aluminum Casting Research Laboratory Consortium	*CMI-Tech Center*	*Stahl Specialty Company*
	North American Die Casting Association	*Wabash Alloys*

Clean, Machinable, Thin-Walled Gray and Ductile Iron Casting Production, Phase III, University of Alabama - Birmingham - The focus of the Phase I study was to develop a consistent method for evaluating the machinability of gray and ductile iron. Test castings were produced in participating foundries, and "hard-to-machine" castings were obtained from foundries and machine shops. A microcarbide dispersed in the pearlite was found to be a significant cause for poor machinability in both laboratory test procedures and in "hard-to-machine" commercial castings. A large body of data on iron processing, properties, and machinability was developed to provide baseline information relating machinability to microstructural characteristics. Castings submitted in Phase II were examined and compared to the baseline data. The baseline data serves as a reference point for assessing the causes of the difference. The baseline data is being used to determine reasons for both superior and inferior machining behavior. Companies began contributing hard-to-machine castings for examination. Analyses produced findings to improve machinability. The primary focus of the current phase will be to continue to identify and determine how the occurrence of microcarbides, silicides, and other objectionable phases can be controlled within the normal foundry process (rather than by heat treatment). Alloy combinations will be explored that will maintain strength while improving machinability. Machining operations will be extended from drilling to include turning, and data will be obtained with higher performance tools including carbides and ceramics. In addition, properties will be measured on selected classes of irons to provide data for linear elastic stress codes that can be used to design castings for reduced mass.

ABI	*Cummins Engine*	*Mercury Marine*
American Foundrymen's Society	*Daimler Chrysler*	*Seele Corp*
Bosch Breaking Systems	*Ford Motor Co*	*Technalysis*
Caterpillar Inc.	*Hiler Industries*	*Waupaca Foundry Co.*
Consolidated Diesel	*Ingersoll Cutting Tools*	*Wells Manufacturing*
Copeland Corporation	*Kohler*	*Wheland Foundry Co.*

Design Parameters for Lead Free Copper Based Engineering Alloys in Permanent Molds, Materials Technology Laboratory - The objective of this research is to determine the tensile, fracture toughness, impact and fatigue properties of 12 copper-base alloys for use in more demanding engineering applications. Permanent mold casting offers improved surface finish, precise and consistent dimensional control and improved mechanical properties. Tensile, fracture toughness, slurry wear, and corrosion properties are not adequately addressed in current ASTM specification (B806-93) for permanent mold copper-based alloys. It covers six alloys in two categories: aluminum bronze and silicon brasses. Data is needed for high copper alloys, high strength yellow brass, silicon bronze, nickel silver, and high manganese brass. The composition limits for these alloys were developed for sand casting and not optimized for the faster cooling rate experience in permanent mold casting. The zinc equivalent in high strength brasses is a useful predictor for ensuring good balance between strength and ductility in particular applications. Corrosion studies show that permanent mold samples experience general surface corrosion whereas sand-cast samples have localized corrosion. Fracture and impact properties are strongly influenced by composition with most alloys exhibiting relatively high values and these values correlate with high tensile elongation.

AB Chance Co.	*Bunting Bearing Corp.*	*Starline Manufacturing Co, Inc.*
American Foundrymen's Society	*H. Kramer & Co.*	

Development of Surface Engineered Coatings for Die Casting Dies, Colorado School of Mines - The objective of this research program is to develop an optimal "coating system" that minimizes the major mechanisms leading to premature die failure. These mechanisms include: heat checking (thermal cracking), and gross cracking; erosive wear; and soldering and corrosion/oxidation. Ultimately, the goals of this research program are: 1) the achievement of increased die-casting die life; 2) increased surface quality of die-cast components; 3) decreased downtime during scheduled production; 4) increased substitution of aluminum die-cast components for steel and cast iron; and 5) decreased in-process (pre-consumer) scrap.

Blue Ridge Pressure Castings	*Hayes Lemmerz*	*North American Die Casting Association*
Hard Chrome	*ISM*	*SPX Contech*

Effects of Externally Solidified Product on Wave Celerity and Quality of Die Cast Products, Ohio State University - The heat and mass transport phenomena which occur in the shot sleeves of cold chamber die casting systems have significant effects on the reproducibility of the die casting process and resulting die cast components. The objective of this project is to increase productivity and improve the quality of die castings. It will develop an improved understanding of the alloy solidification that occurs in the shot sleeve and its effects on the subsequent filling of both the shot sleeve and die cavity during the injection portion of the die casting process.

Briggs & Stratton Corp.	*North American Die Casting Association*
Heick Die Casting Corp.	*Walkington Engineering*

Enhancements in Magnesium Die Casting Die Life and Impact Properties, Case Western Reserve University - The objective of this research is to improve the toughness of cast magnesium alloy products and evaluate the effect these alloys have on the thermal fatigue life of steel dies used in the die casting process. The AM-type magnesium alloys have the capability of providing high toughness. These alloys have to be processed while avoiding entrapment of damaging trace elements and casting discontinuities. This study will establish relationships between processing variables and the resulting alloy toughness and recommend best workmanship procedures and practices for implementation in magnesium die-casting process.

A. Finkl & Sons Co.	*Dow Chemical*	*General Motors*
Chrysler Corporation	*Empire Die Casting*	*Mercury Machine*
CMM Services	*Ford Motor Company*	*North American Die Casting Association*
Crucible Steel	*FPM Heat Treating*	*PNGV*
DCD Technology	*General Die Casters*	*UBE Machinery*

Heat Treatment Procedure Qualification for Steel Castings. Pennsylvania State University - The objectives of the research are to develop, test, and validate heat treatment qualification procedures that can be effectively used by steel foundries to assure casting performance for carbon, low alloy and high alloy steels.

American Steel Foundries	*Milwaukee Steel*	*Pennsylvania Foundry*
Frogswitch	*Missouri Steel Castings*	*Steel Founders' Society of America*
Harrison Steel Castings	*Pacific Steel Castings Company*	

Impurity Limits in Aluminum Bronzes, Materials Technology Laboratory - The objective of this project is to study the effect of impurity elements on the mechanical properties, weldability and heat treatment of two common aluminum bronze alloys C95800 and C95400. Aluminum bronze castings exhibit mechanical properties comparable to steel and stainless steel. The mechanical properties, heat treatment, and weldability of aluminum bronze alloys are needed by design engineers to compare the return on investment of aluminum bronze alloys with corrosion resistant ferrous materials in the pulp and paper industry, potable water supply and treatment utilities, and power generation and distribution. In the case of C95800, ASTM specified properties can be achieved in the presence of all impurity elements except lead. (Lead reduces the yield strength below the minimum specified value.) Impurity elements (such as lead, tin, and bismuth) typically enhance strength but reduce ductility. Thus, ductility is likely the deciding factor in specifying the upper limit for impurity elements. Welding studies found no cracking in air-cooled base alloy samples. However, at higher levels of lead (greater than 0.15%) and bismuth (greater than 0.08%) promoted cracking but samples with lower levels of lead (0.06% and 0.10%) and bismuth (0.03%) did not show any tendency for cracking. In the case of as-cast C95400, like the C95800 alloy, ASTM specified properties can be achieved in the presence of all impurity elements. However, lead and bismuth impurities embrittled C95400 alloys after heat treatment.

AB Chance Company
American Foundrymen's Society
Brost Foundry Co.
Colonial Metals Co.
H. Kramer & Co.

Predicting Pattern Tooling and Casting Dimensions for Investment Casting, Oak Ridge National Laboratory - This project is developing tools for predicting pattern tooling and casting dimensions for investment castings. It will take into account the thermal expansion of wax, wax mold, shell mold, and alloy materials, as well as the solidification characteristics of the casting in the shell mold, taking into account solidification shrinkage, plastic yield, creep, elastic contraction, and mold restraint. To date, a number of findings have been made: relevant properties of shell materials include both thermophysical and mechanical properties; dimensional changes of the shell mold are affected by the thermal expansion characteristics of the shell; prefiring temperatures and holding times affect the thermal expansion/contraction properties of shells; and a key point in the thermal expansion characteristics is the "Sinter Start" temperature.

American Foundrymen's Society
Howmedica, Inc.
Howmet Corp.
MINCO, Inc.
PED Manufacturing Ltd.
Precision Metalsmiths, Inc.
Spokane Industries

Process Parameters for Lead-Free Copper-Base Engineering Alloys in Permanent Molds, Materials Technology Laboratory - The objectives of this research are to develop process parameters such as evaluation of mold materials, improvement in casting fluidity, grain refinement, perform water and computer modeling to explain mold filling and to evaluate high phosphorous lead-free brass for plumbing applications. Different mold materials were tested using a thermal cycling set-up and their performance was ranked after 6000 cycles. The fluidity of tin bronze (C90700) and lead free red brass as influenced by the addition of Al, Mg, P, Mn, Ni and Si was studied. Grain refinement studies on silicon brass (C87500), silicon bronze (C87600) and lead free red brass were completed. The effect of grain refinement on the hot tearing resistance was also evaluated.

AB Chance Co.
American Foundrymen's Society
Bunting Bearing Corp.
H. Kramer & Co.

ZCA-9 Creep Resistant Alloy Development, International Lead Zinc Research Organization, Inc. (ILZRO) - This program will develop zinc-based die casting alloys suitable for processing by the hot chamber die casting process that have improved creep strength. Many applications such as fasteners in automobile underhood applications require zinc alloys to maintain a minimum load under long term loading. The hot chamber die casting process, by which almost all zinc alloys are cast, is known to be a more efficient casting process than the cold chamber technique used to die cast aluminum and other alloys. The lower casting temperature of zinc alloys allows for greater precision in the cast parts, reducing both energy and materials waste. However the capabilities of zinc die castings are limited with respect to sustaining loads for long times at elevated temperatures. Under such conditions, a slow deformation, termed "creep", occurs. Creep is common in all metal alloys under such conditions, but the commonly used zinc casting alloys are less creep resistant than other higher melting temperature alloys, meaning that the cold chamber die casting process must be used to obtain the benefits of higher creep resistance.

Die Makers
Eastern Alloys
North American Die Casting Association

Development of a Fatigue Properties Data Base for Use in Modern Design Methods, Climax Research Services - The objective of this project is to develop a comprehensive database of strain-life fatigue data for graphitic cast irons. Specifically, the structural grades of gray iron, ductile iron, austempered ductile iron and compacted graphitic iron will be included. Each grade will be evaluated with microstructures corresponding to two cast section sizes for comparison, thus resulting in two materials to be described per grade of iron. The database of cast iron fatigue properties will be suitable for modern design techniques. This will enable designers to use modern durability modeling to develop more precise and efficient cast iron components. Cast iron producers will benefit by expanded and newly opened markets while end-users will realize cost savings in both component development and manufacture. Iron foundry expenditures will also benefit from the reduced weight of metal in the lighter more efficient component design.

American Foundrymen's Society
Applied Process Technologies
Caterpillar
Hayes Lemmerz International
Intermet
Lucas Varity
Wheland Foundry

Gating of Aluminum Permanent Mold Castings, Case Western Reserve University - This program will examine the gating of vertically-parted aluminum permanent mold castings through a combination of experiments and computer simulations to develop improved gating designs. The improved gating systems will aim to eliminate molten metal surface turbulence during mold filing in order to reduce casting defects, maximize thermal gradients during solidification to aid metal feeding, provide necessary risers as a source of feed metals. The potential benefits of improved gating design are higher casting yields, lower scrap rates, lower defect contents, and with fewer initial design iterations, thus resulting energy efficiency gain in the process.

American Foundrymen's Society

Mechanical Properties Structure Correlation for Commercial Specification of Cast Particulate Metal Matrix Composites, University of Wisconsin - Milwaukee - The objective of this research is to evaluate mechanical testing and structural characterization procedures for commercially available particulate metal matrix composites, in particular for aluminum alloy - silicon carbide particle composites. This study will provide quantitative comparative data generated cooperatively by material suppliers, casting producers and casting users in the U.S. Automotive Materials Partnership. It will help establish industry procedures for mechanical testing and structural characterization.

American Foundrymen's Society

Systematic Microstructural Corrosion Performance Evaluation of N-3MN and CK-3MCUN High Molybdenum Stainless Steel, University of Tennessee - There is a need for a thorough and systematic investigation of the microstructural relationships and corrosion performance of high alloy stainless steel castings. This is of paramount importance because a dearth of information exists for optimum engineering usage of the newer and more corrosion resistant alloy systems. This research will systematically document the microstructural phase evolution in two types of high molybdenum stainless steel castings as a function of solution heat treatment parameters, and then relate the microstructure to corrosion performance.

Atlas Foundry and Machine
Esab Welding & Cutting Products
Keokuk Steel Casting
Quaker Alloy, Inc.
Steel Founders' Society of America
Welding Research Council
Wollaston Alloys, Inc.

Thin Section Steel Castings, Pennsylvania State University - Current limits on the wall thickness of sand castings is approximately 6mm. This limit is associated with the manufacturing techniques related to mold and core dimensional control. The investigations and data analysis carried out in the dimensional control program showed that it is possible to produce steel castings in the USA to tighter tolerances than those specified in ISO 8062:1994 *Castings - System of dimensional tolerances and machining allowances.* Even with this better than average capability there is a need to produce castings with 4mm wall thickness to produce more efficient casting designs which allow the mechanical properties of steel to be exploited. The primary materials being evaluated represent the carbon and stainless steel families. Results so far have shown that it is possible to make both of these alloys fill a length of 20" for wall thicknesses of 4mm, this is well beyond the typical limit for 6mm which is usually stated as 12". The amount of superheat in the steel is the strongest variable affecting the ability to fill. The ability to hold the core in position relative to the mold has been confirmed to have a major effect on the ability to fill. One of the unforseen limitations to the experimental work was the inability of many of the solidification packages to predict, with any degree of confidence, the point at which the thin wall castings would solidify. Dr. Robert Voigt has now found one package which will predict the point of solidification with some certainty when compared to the test castings. This should help in designing more complex shapes. An interesting side benefit of this thin wall work is that the castings made will not require risers due to the high solidification rate, this should improve the cost effectiveness of these products. The potential of this program is to offer much more efficient designs of castings, reductions in energy costs both inside and outside of the foundry.

Durametal Corp.
GM Powertrain
Pennsylvania Steel
Pelton Casteel
Quaker Alloy
Spokane Industries
Steel Founders' Society of America

Thin Wall Iron Castings, University of Alabama - Foundries specializing in automotive castings must develop new processes and materials that reduce overall car weight to meet federally mandated fuel economy standards, without sacrificing performance. In order to meet these needs, automakers have increasingly turned to lighter weight materials, and castings continue to be a prime target. For cast iron to regain lost markets it must be better engineered to achieve its full potential. At present time, iron castings cannot be routinely produced in sand mold with thickness less than 3 mm. In addressing this need, research is being carried out to develop the technology for producing commercial iron castings with wall thickness less than 3 mm. The objective of this program is to develop the technology to produce commercial castings of gray, ductile, and compacted graphite iron with wall thickness less than 3mm. The project will investigate both the metallurgical treatment required for molten iron, and the mold and core-making techniques needed to reach the program goals.

ABC Coke
American Colloid
American Foundrymen's Society
Badger Mining
Brillion Iron Works
Caterpillar, Inc.
Carrollton Casting Center
Chrysler Foundry
Citation Corp.
Elkam Metals Co.
Fairmont Minerals
Ford Motor Co.
Foseco, Inc.
Georg Fischer DISA A/S
GM Powertrain
Hickman Williams & Co.
Intat Precision
Intermet Technical Service
K&P Agile, Inc.
Magma Corp.
Miller & Co.
Rio Tinto Iron & Titanium
Simpson Technologies
Superior Graphite
UES Software

Environmental Technologies

Non-incineration Treatment to Reduce Benzene and V.O.C. Emissions from Green Sand Molding Systems, Pennsylvania State University - Green sand foundries are under increasing pressure to reduce benzene and volatile organic carbon (VOC) emissions during pouring, cooling and shakeout. Conventional incineration systems to treat stack gases are expensive to operate and difficult to maintain. Alternative pollution prevention strategies must be developed to comply with ever more demanding air quality requirements. Full-scale plant trials at green sand foundries have shown that simple non-incineration Sonoperoxone™ (SP) treatment systems or a combination of Sonoperoxone™ Plasma (SPP) treatment can significantly reduce emissions. This project is developing a fundamental understanding of SP and SPP processing. Plant trials and laboratory tests will be conducted to further optimize systems that have been already installed at production foundries. Performance characteristics and effectiveness of non-incineration treatments to significantly and cost effectively reduce benzene and VOC emissions for green sand foundries will be demonstrated.

American Foundrymen's Society
Furness-Newburge, Inc.
Neenah Foundry Company
Wheeland Foundry

Steel Foundry Refractory Lining Optimization: Electric Arc Furnace, University of Missouri - Rolla - Researchers at UMR have been working with the wrought steel industry to better understand the mechanisms, which govern the wear of furnace refractories. Many new refractory materials have been developed during that same period and have been used successfully by wrought steel producers. But, largely because of elevated costs, these materials have not found widespread usage in steel foundries. In the current project, the researchers at UMR will build on the experience they gained with wrought steel production to assist steel foundries. The main focus of the project is to optimize the refractory systems used in electric arc furnaces (EAFs) in the steel foundries. This will be accomplished by determining the best combinations of refractory materials, slag compositions, and melting practice to increase the refractory life in EAFs.

ABC Rail Products
American Cast Iron Pipe Co.
Atchison Casting
Baker, Refractories
Electroalloys Corp.
Falk Corporation
GH Hensley Industries
Harrison Steel Castings
Keokuk Steel Castings
Missouri Steel Castings
North American Refractories
Pelton Casteel
Quaker Alloy, Inc.
Steel Founders' Society of America
Varicast, Inc.
Wahl Refractories
Wellsville Fire Brick Co